CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

INCLUDING PRESTRESSED CONCRETE

FEBRUARY 1960 VOL. LV. NO. 2

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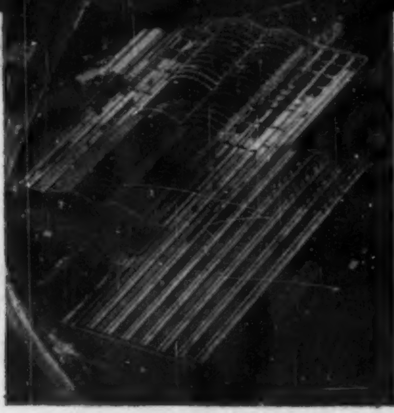

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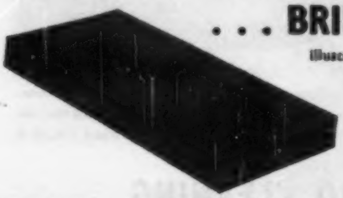

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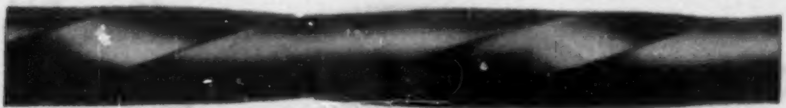

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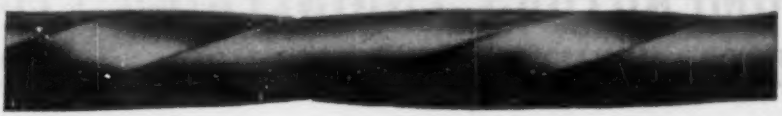

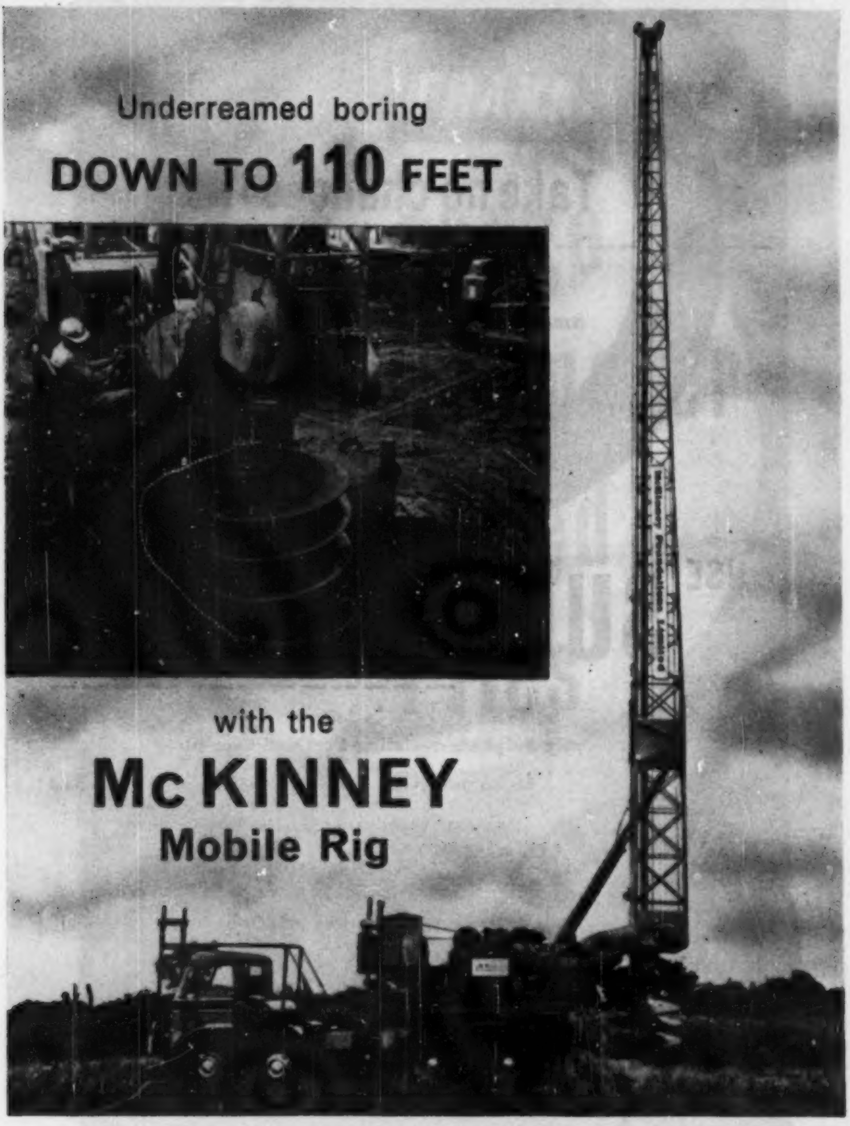
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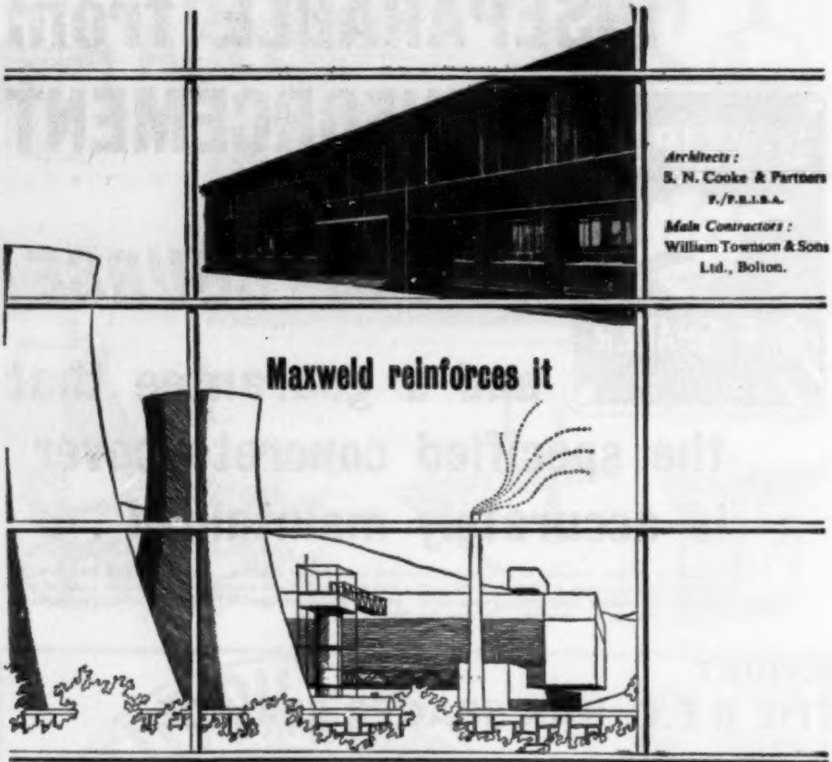
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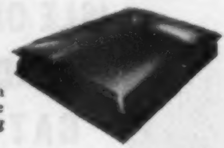

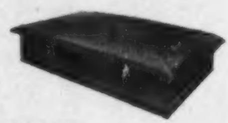

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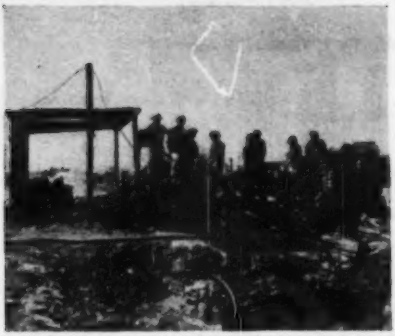
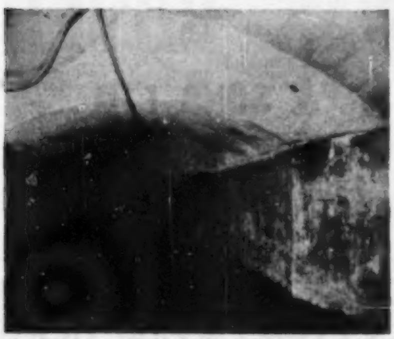


COLGROUT mixing plant at a South African Gold Mine.



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The main pump chamber of a South African Gold Mine 6,000 ft. below surface and lined with Colcrete.

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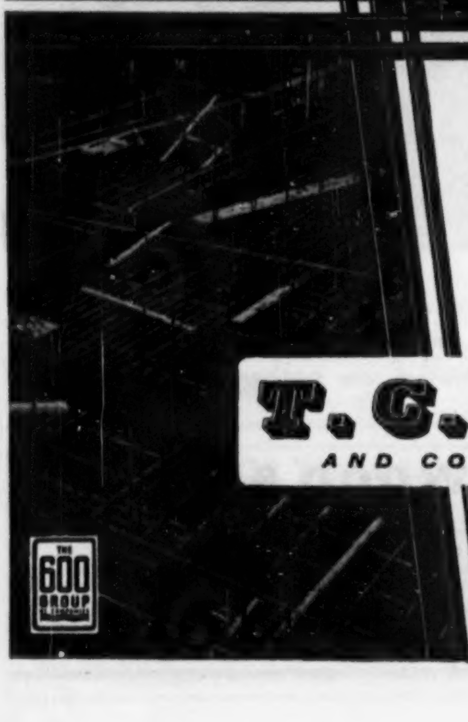

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Volume LV, No. 2. LONDON, FEBRUARY, 1960.

EDITORIAL NOTES

A Code for Prestressed Concrete in Buildings.

ON occasion, the view has been expressed in these notes that codes should embody only practice that has proved to be sound and, by inference, premature publication of recommendations which have not stood the test of time must be avoided. In this respect, the British Standards Institution has done well, since it has not previously rushed into print with a code containing recommendations for the use of prestressed concrete in buildings but has waited nearly two decades after the general introduction of prestressed concrete into this country before publishing its code of practice.* So many prestressed concrete structures have now been built in this country with so many systems, and so many engineers have now obtained experience, successful and otherwise, that the publication of such a code is timely. As is to be expected, the Code owes much to the "First Report on Prestressed Concrete" issued by the Institution of Structural Engineers in 1951 which, though well received at the time, may be considered to correspond to the provisional recommendations issued in Germany in 1953 and the tentative recommendations published in the U.S.A. in 1958.

The technical recommendations contained in the Code should, in the main, be acceptable to most practising engineers. We would, however, criticise the assumption that prestressed concrete designs are entrusted only to "chartered structural or civil engineers experienced in the use of concrete" because, in the first place, many eminent foreign engineers and others would be excluded, and secondly, the design of prestressed concrete is specialised and fraught with problems to deal with which a practitioner in ordinary reinforced concrete may not have had the necessary experience. Also, it is unfortunate that the notation which is becoming standardised because of its inclusion in the code for reinforced concrete buildings is not adopted in all cases where applicable. It is regretted that some of the terminology will do much to perpetuate some words to which are given meanings other than their true meanings. An example is "loss" of prestress when reduction of the effective prestressing force is meant, since the

* British Standard Code of Practice, CP.115 (1959): "The Structural Use of Prestressed Concrete in Buildings". (British Standards Institution. Price 8s. 6d.)

compressive force imposed on a member is not always lost but, due to friction and some other causes, may be distributed differently. We have expressed previously our views on the term " tendon " to describe prestressing steel of all kinds; the result of our competition for a more appropriate word to describe these components is given on page 71.

The foregoing are perhaps small matters in a document that, with few notable exceptions, deals adequately with those aspects of prestressed concrete on which a designer requires guidance. A review of the recommended stresses and a comparison with German and American practice are given on page 73. One recommendation calling for comment is that there is no limit to the principal tensile stress due to the combination of the effects of prestressing, bending, and shearing so long as reinforcement is provided to resist the entire shearing force. This omission is so contrary to practice in reinforced concrete in this country that, without adequate explanation, it is questionable and may lead to defective design in the hands of those not fully conversant with prestressed concrete. Another omission, in our view, is the failure of the Code to describe the " recognised general principles relating to the design of prestressed concrete ", and to give the basic formulæ. Where else than in a code of practice, and especially in the first in this country, would an engineer expect to find such principles ? Even in the code for reinforced concrete the basic principles are described, although these have been known for upwards of fifty years, and the formulæ for the load-factor method are given.

The Code does deal, however, in a useful manner with the method of calculating the strength of beams at incipient failure, and comprehensively with the reduction of the prestress due to friction and some other causes. The reduction coefficients cover a wide range but apply only to normal conditions and known materials. Coefficients for exceptional conditions and new processes can be established by test. It may be thought that some of the coefficients are slightly high, but in a general recommendation this is as it should be. There is nothing to prevent, and much in favour of, an engineer making tests to determine coefficients which may be more applicable to the materials and equipment it is proposed to use. The stiffness of a metal sheath may affect considerably the frictional resistance, and there is likely to be some reduction of prestress due to friction between the wires in a group of wires forming a curved cable if all the wires are not tensioned at the same time; these potential causes of reduction are not mentioned in the Code, nor are recommendations given relating to such factors as the reduction of effective force due to the rope-tightening effect in strands, that is wire ropes, or the effect of torque due to the lay of the wires in ropes. Although wire ropes, which are by no means a novelty today, are included in the prestressing steels permitted, there are no further references thereto, not even in the clause dealing with the permissible stresses in the prestressing steel; in fact this clause deals with two only out of the several permitted forms of " tendon ".

The recommendations regarding anchoring the prestressing steel in post-tensioned members should be amplified. Although it is stated that the anchors should be capable of maintaining the prestressing force under the most adverse conditions of loading, no margin of safety is expressed for the strength and other properties of the anchoring devices, and it may be that these devices may therefore

constitute the weakest part of the construction. It is also stated that the principal tensile stress in the concrete due to the anchors should be "minimised" and that reinforcement may be necessary to resist such stresses; but no recommendations are given concerning what stress is allowable with or without reinforcement, nor what local compressive stress due to the anchors is permissible as is given in some other codes. It is to be expected that a code would be much more explicit on the design of the ends of beams in view of the fact that experience shows this part to be so vulnerable.

Among more secondary matters, mention might be made of the casual reference to statically-indeterminate structures; the omission of guidance to the reduction of the stresses in a beam when the ratio of length to breadth exceeds thirty, and likewise what modification is required if the ratio of depth to breadth exceeds two-and-a-half; the loading due to wind and snow is classified as being of short duration, but this may be far from true in the case of snow; and the note relating to the consideration of the effect of the reduction of prestress on the compressive stresses at transfer which seems to be more applicable to the tensile stresses in the concrete.

It is, of course, easy to criticise a first attempt as this Code is, and no doubt many matters, including some of those in the foregoing, will be given attention when the Code is revised. Since it is likely that revision will not take place for several years, it may be worth while for the Institution to issue in the near future a short memorandum giving supplementary recommendations on some matters; a precedent for this procedure is the memorandum issued at one time in connection with the by-laws of the London County Council for reinforced concrete.

"A Word is Wanted"—Result of Competition.

MANY entries were received from many countries in the competition, announced in this journal for September last, for a word to describe the tensioned steel or other material or means used to prestress concrete. The assessor has awarded the prize of £25 to Mr. Paul L. Sowerby, of West Didsbury, Manchester, for the word STRICTOR. In our next number we propose to give the assessor's report and some of the other words submitted.

The Use of English.

READERS of this journal who are in agreement with the opinions expressed in some of our Editorial Notes in which the lack of accuracy of expression in the writings of engineers is deplored, will be pleased with the suggested revised requirements for entry to the Universities of Oxford and Cambridge, since it is proposed to include a compulsory paper on "the use of English". The report issued by Oxford states: "We think that there will be wide agreement that far too high a proportion of undergraduates at the time of their matriculation find undue difficulty in expressing themselves clearly and accurately in their own language". The report issued by Cambridge contains a similar condemnation of the present system which results in a low standard of English writing among so many undergraduates.

Book Reviews.

"Advanced Structural Design." By C. S. Benson. (London: B. T. Batsford, Ltd. 1959. Price 50*s*.)

This is an unusual book in that, without preamble or explanation, full calculations and some details are given for the design of complete structures including a trough-shape coal bunker, a water tower, a grain silo, an office building, and the foundation of a retort house in reinforced concrete. Steel structures include a coal bunker in a boiler house, a water tower, a road bridge of 75 ft. span, a pump-house, a shed 120 ft. wide, a two-bay frame, a garage with a north-light roof, a theatre balcony, a crane gantry, and a signal gantry. A brick chimney and vaults with brick arches are included.

The jargon and contractions common in design offices are used, and may present some difficulty to inexperienced readers for whom the book is evidently intended in spite of the word "advanced" in the title. Also it may not always be clear which formula is being used since in many cases numerical substitution is made without identifying the general expression. On the other hand, in some instances the full derivation of a formula is given. In general the detailing is good, although exception may be taken in some cases; for example, the absence of horizontal bars in the lower part of the wall of a square tank and the general complicated nature of this particular detail.

In each example the design relates to a structure of specified dimensions; the planning of the structure and its supports is not described. The design finishes at the stage when the calculations and sketches would be passed to a designer-draughtsman to prepare the working drawings; the book would be improved by including some drawings of this nature, especially for the reinforced concrete structures.

"Surveying." By A. Bannister and S. Raymond. (London: Sir Isaac Pitman & Sons, Ltd. 1959. Price 45*s*.)

The principles of land and hydrographic surveying are dealt with in detail in the four hundred pages comprising this book, in which numerous examples are given. The construction and operation of instruments in common use, and some which have been developed recently, are described. The book is intended primarily for students preparing for professional examinations, but many bibliographical references to sources of more detailed or advanced information are given. Some particulars of field astronomy are given. Among the modern methods of surveying is the measurement of distances by reflected light or radio waves. The chapter dealing with various methods of photographic surveying includes stereoscopic aerial photography.

"The St. Lawrence Seaway." By T. L. Hills. (London: Methuen & Co., Ltd. 1959. Price 12*s*. 6*d*.)

A general account is given of the development and construction of the navigable waterway from Montreal to the Great Lakes, and a description in non-technical language of the organisation and carrying out of the extensive civil engineering works is included. These works comprise many large concrete structures such as the Long Sault dam, an arched gravity structure about 2900 ft. long and having a maximum height of 145 ft., and the Iroquois dam, a buttress gravity structure 2540 ft. long and 67 ft. high.

"Der Stahlhochbau." Volume II. By C. Kersten and Werner Tramitz. (Berlin: Wilhelm Ernst & Sohn. 1959. Price 29.60 D.M.)

In this sixth edition of the second volume of the late C. Kersten's guide for students and practising engineers on structural steelwork in buildings there are chapters on frames, cantilever construction, light-weight buildings, lattice-roof girders, buildings of large span, crane beams, roof coverings, roof-lights, glazing, windows, doors, and gates. The importance of correct constructional details is emphasised and is illustrated by more than five hundred diagrams. There are numerous fully-worked examples.

"Technischer Strahlenschutz." By Thomas Jaeger. (Munich: Karl Thiemig. Price not stated.)

The subject is high-density concrete for shielding atomic power plants and the disposal of radioactive wastes. The book is based upon research in the U.S.A. and Great Britain.

Book Received.

"Sculpture in Ciment Fondu." By J. W. Mills. (London: Contractors' Record, Ltd. 1959. Price 16*s*.)

Stresses Permissible in Prestressed Concrete.

By P. W. ABELES, D.Sc., M.I.Struct.E.

THE stresses recommended in the new Code[1] for the design of members of prestressed concrete are discussed in the following and are compared with the corresponding stresses given in the German Recommendations[3] and the U.S.A. Recommendations.[2] The new Code replaces an earlier report.[4]

Compressive Stresses Permissible at Transfer.

In the B.S. Code it is recommended that the compressive stress in the concrete at transfer should not exceed 50 per cent. of the crushing strength of works-cubes at twenty-eight days, or 40 per cent. when the prestress is distributed more or less uniformly over the cross-section of the member, and in no case more than 3000 lb. per square inch. However, since creep increases when the ratio of stress to strength exceeds $\frac{1}{3}$,[5] and sometimes when it is less,[6] it is advisable to restrict the stress to 40 per cent. of the crushing strength irrespective of the distribution of stress as was recommended in an early report[4]. The U.S.A. Recommendations give 60 per cent. of the crushing strength of cylinders which is equivalent to about 40 per cent. of the strength of cubes if the strength of a cylinder is two-thirds that of a cube. In the German Recommendations the crushing strength at transfer is assumed to be 80 per cent. of the specified strength of the concrete, of which there are three types, having strengths varying from 4260 lb. to 8520 lb. per square inch. The stresses permissible at transfer are given as a percentage of the strength, namely: for tee-beams, and hollow beams bending in one plane, 42 to 54 per cent.; for rectangular beams bending in one plane, 44 to 58 per cent.; and for members in direct compression 35·5 to 46 per cent. The greater percentage applies to concrete having the lower strength.

Compressive Stresses Permissible at Working Load.

It is recommended in the Code that the compressive stress in bending due to the working load should not exceed one-third of the crushing strength of cubes at twenty-eight days except at the supports of continuous beams and other statically-indeterminate structures in which a stress of 40 per cent. of the crushing strength is recommended. The compressive stress recommended in direct compression is a quarter of the crushing strength. The permissible stresses due to the greatest working load may be exceeded by up to 25 per cent. if the excess is due solely to the effect of wind.

The corresponding stresses in the U.S.A. Recommendations are 40 per cent. and 45 per cent. of the crushing strengths of cylinders and are equivalent to 27 per cent. and 30 per cent. of the strengths of cubes if the ratio of the strengths of cylinders and cubes is two-thirds. The stresses permitted at working load by the German Recommendations are relatively small and are 1560 lb. to 2270 lb.

1.—British Standard Code No. 115 (1959): "The Structural Use of Prestressed Concrete in Buildings".
2.—"Tentative Recommendations for Prestressed Concrete." Journal of American Concrete Institute, January, 1958.
3.—"Spannbeton.—Richtlinien für Bemessung und Ausführung." (DIN 4227, 1953).
4.—"First Report on Prestressed Concrete." Institution of Structural Engineers (1951).
5.—P. W. Abeles. "Notes on Materials for Prestressed Concrete." *Concrete and Constructional Engineering*, September, 1957.
6.—P. W. Abeles. "Losses of Prestressing Force." *Concrete and Constructional Engineering*, September, 1958.

TABLE I.—PERMISSIBLE TENSILE STRESSES (B.S. CODE).

STRENGTH (lb per sq.in)			3000	4500	6000	7500
PRESTRESSED CONCRETE	PRE-TENSIONED STEEL	CASE A			300	325
		CASE B			450	500
	POST-TENSIONED STEEL	CASE A		175	200	225
		CASE B		275	300	325
ADDITIONAL CONCRETE		CASE A	200	250	300	
		CASE B	300	375	450	

per square inch for rectangular beams, 1705 lb. to 2415 lb. per square inch at the corners of rectangular beams subjected to bending in two planes, 1420 lb. to 2130 lb. per square inch for tee-beams, and 1130 lb. to 1850 lb. per square inch for members subjected to direct compression. In each case the lower stress applies to concrete having the lower strength as described for the stresses permitted at transfer.

Tensile Stresses Permissible at Working Load.

Some designers prefer there to be no tensile stress in the concrete at working load, and this condition is satisfactory if economy is not important, or if it is not essential to reduce the member to the least possible depth. There should be no tensile stress in members, such as turbo-generator bases, which are subjected to a large number of cycles of dynamic load of high frequency. In other cases there is no objection structurally to the existence of tensile stresses within certain limits or to temporary hair-cracks.

The serviceability of a structure at working load may be impaired if cracks are produced. This may happen at a high tensile stress with well-bonded steel in a monolithic member or at a low stress with badly bonded steel. It is possible to prevent cracks when tensile stresses are produced at working load only if it is ensured that no cracks occur before the prestress is applied. In addition to careful design, close supervision of the work and effective curing are essential if freedom from cracks is to be achieved. The permissible tensile stresses in bending as recommended in the Code for members with pre-tensioned and post-tensioned steel are given in *Table* I in which Case A applies when the greatest working load occurs frequently or is of long duration or both, and Case B applies when the greatest working load occurs rarely and is of short duration. The pressure of the wind and the weight of snow on roofs are mentioned in the Code as examples of the latter case. These stresses may be increased by not more than 250 lb. per square inch provided that tests show that the increased stress is not greater than three-quarters of the stress at which the first crack appears as determined by a test. In such a case, therefore, for concrete with a crushing strength of 7500 lb. per square inch at twenty-eight days the greatest tensile stress permissible is 750 lb. per square inch with pre-tensioned steel or 575 lb. per square inch with post-tensioned steel. When the increased stresses are adopted the greatest prestress in the concrete should be at least 1500 lb. per square inch and the pre-tensioned steel should be well distributed; post-tensioned steel (which is usually less well distributed) should, if necessary, be supplemented by non-tensioned steel bars provided near the tensile face of the concrete.

Experience shows that it is possible to avoid cracking even when such high tensile stresses occur. Tensile stresses of 750 lb. per square inch in roofs, and 650 lb. per square inch in road bridges have been adopted with satisfactory results, the adequacy of the design in these cases being controlled by performance tests. When such tests are made, the factor of safety against cracking, despite the higher stresses, is greater than that of a member with post-tensioned steel designed to resist lower tensile stresses but made under poor supervision. If the concrete is inadequately cured, cracks due to shrinking of the concrete may occur before the prestress is applied.

A method of design, particularly suitable for structures with no applied finishes and which is economical and complies with the recommendations of the Code, is one in which there is no limit to the tensile stresses caused in the concrete by occasional heavy loads, provided that no tensile stresses are caused by the normal load. In this case the factor of safety required against failure must be

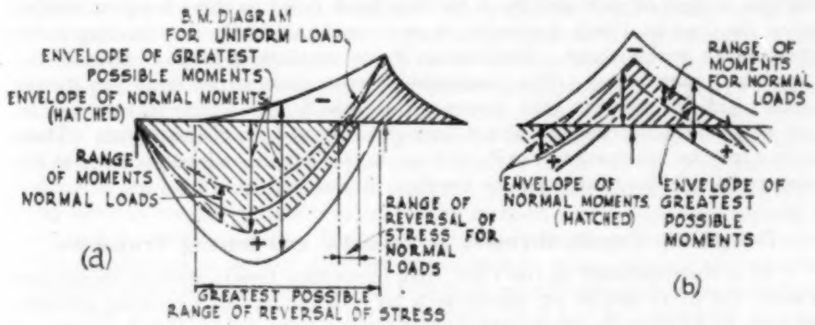


Fig. 1.

provided for the occasional load, thereby restricting the widths of the cracks. If the occasional load is likely to operate for more than a very short time, it is necessary to investigate the deflection of the member. This method is particularly useful in the design of continuous beams or beams with cantilevered ends in which the load on some spans may cause reversals of bending moments. The envelopes of the diagrams of the greatest possible bending moment and greatest normal bending moment on a beam with a cantilever at one end are shown in *Fig.* 1a. If the beam is designed to resist the entire range of bending moments with little or no tensile stress in the concrete a very large member is required. If, however, the load causing the greatest possible bending moments is likely to occur rarely, if at all, the method described in the foregoing would lead to a more economical beam. A cantilever will generally be subjected to the full working load and it is therefore necessary to design it to resist the maximum bending moment at the support. The occurrence of the distribution of loading causing the greatest possible bending moments at the supports of a continuous beam (*Fig.* 1b), however, may be rare and generally the greatest bending moment at a support would be less than the greatest possible bending moment.

In a member which is not exposed to the weather or to a corrosive atmosphere, the permissible tensile stresses in accordance with the U.S.A. Recommendations

are (a) for a member with pre-tensioned steel, 600 $\sqrt{\frac{f'_c}{10{,}000}}$ lb. per square inch; (b) for a member with post-tensioned steel, 300 $\sqrt{\frac{f'_c}{10{,}000}}$ lb. per square inch. In these expressions f'_c is the crushing strength of cylinders. For example, if f'_c is 6000 lb. per square inch, the permissible stresses are 480 lb. and 240 lb. per square inch. These stresses are based on the assumption that the modulus of rupture has the relatively small value of 750 $\sqrt{\frac{f'_c}{10{,}000}}$. The permissible stress (a) may be exceeded if it is demonstrated by tests that the behaviour of the structure under service conditions is acceptable. It is recommended, however, that there should be no tensile stresses in bridges, or at the joints of members composed of precast elements, but this recommendation is often ignored and, instead, designs of roofs and floors are sometimes based on there being no camber when the dead load only is present; in such cases hair-cracks may develop under the greatest working load. The German Recommendations permit "limited" or "partial" prestressing. The permissible tensile stress varies from 570 lb. per square inch for concrete with a strength of 4260 lb. per square inch to 850 lb. per square inch for concrete with a strength of 8520 lb. per square inch. These values may be increased to 710 lb. and 990 lb. per square inch respectively at the corners of members subjected to bending in two planes.

Temporary Tensile Stresses at Transfer and During Transport.

It is recommended in the Code that temporary tensile stresses should not exceed 175 lb. to 225 lb. per square inch for concrete having a crushing strength of 4500 lb. to 7500 lb. per square inch at twenty-eight days. However, greater stresses may be incurred for periods not exceeding forty-eight hours. Tensile stresses in the ends of beams with pre-tensioned steel should preferably be less than the foregoing stresses, as imperfect compaction of the concrete in these regions may give rise to tensile stresses which may exceed the calculated stresses and which may cause undesirable cracking.

When calculating the stresses likely to occur during transport and erection of a member, allowance should be made for the probability of impact; in the writer's opinion, it is desirable to allow an impact factor of $1\frac{1}{2}$ to 2, and to limit the permissible tensile stress to not more than 500 lb. per square inch.

In the U.S.A. Recommendations the permissible stresses are as follows: monolithic member without non-tensioned steel: 300 $\sqrt{\frac{f'_c}{10{,}000}}$; monolithic member with non-tensioned steel: 600 $\sqrt{\frac{f'_{ct}}{10{,}000}}$; member composed of separate blocks and with non-tensioned steel: 300 $\sqrt{\frac{f'_{ct}}{10{,}000}}$, in which f'_{ct} is the crushing strength of cylinders at the age at which transfer takes place. Relating the permissible stress to $\sqrt{f'_{ct}}$ is not entirely satisfactory.

The permissible tensile stresses specified in the German Recommendations

vary from 425 lb. per square inch for concrete with a strength of 4260 lb. per square inch to 640 lb. per square inch for a strength of 8520 lb. per square inch.

Principal Tensile Stresses.

In some regulations, permissible principal tensile stresses are specified for working-load conditions only. It is, however, essential to provide a specific factor of safety against failure due to shearing as such a failure occurs suddenly with little warning, and the stresses at failure are therefore of much greater importance. It is recommended in the Code that the greatest principal tensile stresses at the load causing failure should not exceed 300 lb., 350 lb., and 400 lb. per square inch in concrete having crushing strengths of respectively 4500 lb., 6000 lb., and 7500 lb. per square inch at twenty-eight days. The corresponding stresses at working load are 125 lb., 150 lb., and 175 lb. per square inch. In all cases, the principal tensile stress should be computed for the effective prestress and the stresses due to the specified loading. When the principal tensile stresses at working load exceed the permissible values, reinforcement to resist shearing should be provided. If the principal tensile stress is more than 1½ times the tensile stress permissible at working load, the reinforcement should be designed to resist the entire shearing force; for stresses between 1 and 1½ times the permissible stress the proportion of the shearing force to be resisted by the reinforcement should be interpolated linearly from 0 to 100 per cent. If the principal tensile stress at the load causing failure exceeds the permissible stress, the entire shearing force in excess of that resisted by the inclined prestressing steel should be resisted by reinforcement. It is generally advisable to provide binders unless the calculations show that they are not needed to resist shearing and complete freedom from cracks due to shrinking before the prestress is applied can be assured.

The permissible principal tensile stresses need not be considered to apply at sections where the effects of bending predominate, but only at those sections where shearing is more important, since the suddenness of failure due to shearing makes such a failure potentially more dangerous than the gradual failure due to bending, and while cracks caused by bending due to occasional overloading disappear when the overload is removed, diagonal cracks due to shearing do not close unless inclined cables are provided, and therefore constitute a permanent weakness.

TABLE II.—PRINCIPAL TENSILE STRESSES (GERMAN RECOMMENDATIONS).

LINE	CONDITION	PERMISSIBLE STRESS (lb. per sq. in.)		
		(a) SHEAR ONLY	(b) TORSION ONLY	(c) SHEAR + TORSION
(1)	WHEN DESIGN PERMITS NO TENSILE STRESS DUE TO BENDING AT WORKING LOAD	114 - 172	85 - 142	142 - 213
(2)	WHEN DESIGN PERMITS TENSILE STRESS DUE TO BENDING AT WORKING LOAD	227 - 341	170 - 284	284 - 426
(3)	AT LOAD CAUSING FAILURE	454 - 682	341 - 568	568 - 852

High values correspond to strength of 8520 lb. per square inch
Low " " " " " 4260 " " " "
Intermediate values obtained by linear interpolation

The stresses which are given in the U.S.A. Recommendations are intended to ensure that failure due to shearing cannot occur before failure in bending, and are based on the yield stress of the steel and the strength of the concrete. The writer considers it doubtful whether the stresses are sufficient for the purpose.

In the German Recommendations permissible principal tensile stresses are specified for shearing only, twisting only, and combined shearing and twisting, and are given in *Table* II. The smaller stresses are for concrete having a strength of 4260 lb. per square inch and the larger for a strength of 8520 lb. per square inch. No calculations for the shearing reinforcement are required if the permissible stress at the load causing failure is not greater than the stress in line (2) of *Table* II. Sufficient well-distributed reinforcement must be provided to resist the entire tensile force due to the principal stress wherever the stress exceeds three-quarters of the stress in line (2). If the stress exceeds the appropriate stress in line (3), the cross section must be increased or the stress reduced by increasing the prestressing force. Binders must always be provided in beams, even if the principal stress is less than those given in lines (1) and (2). It is surprising that the principal stresses permitted in partially prestressed members exceed those in fully prestressed members. This requirement is probably based on the assumption that with partial prestressing a smaller factor of safety against cracking may be allowed. This assumption may be true when cracking due to bending is being considered, but it seems better to ensure that a larger factor of safety against cracking due to shearing is obtained in view of the suddenness with which failure due to shearing occurs.

Permissible Stress in Bending in Concrete at Load Causing Failure.

In the Code it is recommended that, when the steel is initially stressed to between 60 and 70 per cent. of its strength, the mean compressive stress in the concrete at the load causing failure may be assumed to be 40 per cent. of the cube strength, and the depth of the centroid of the stress-block at the load causing failure may be assumed to be 40 per cent. of the depth to the neutral plane. The stress given in the U.S.A. Recommendations is 0·85 f'_c, which corresponds to 56 per cent. of the strength of cubes when the ratio of the strength of a cylinder to the strength of a cube is two-thirds, and 51 per cent. when this ratio is 0·6. The stress specified in the German Recommendations is two-thirds of the strength of cubes; the distribution of stress assumed, however, is such that the results obtained are about the same as those given in the foregoing.

Stress Permissible in Steel at Transfer and Working Load.

Practice in connection with the permissible stress in the steel at transfer differ considerably. In France, tensioning stresses of up to 90 per cent. of the tensile strength or the yield-point stress are permitted. The German Recommendations specify that the stress must not exceed 55 per cent. of the tensile strength or 75 per cent. of the yield stress or proof stress, whichever is the less. Although 55 per cent. is low, it is preferable to 90 per cent., since at the higher stress a very large part of the elongation of the steel (and consequently its ductility) are no longer available. The initial stress in pre-tensioned steel may be increased to a maximum of 80 per cent. of the yield stress or proof stress, and if friction

occurs the stress at working load in post-tensioned steel may be increased by 5 per cent.

It is recommended in the Code that the initial tensioning stress should not exceed 70 per cent. of the strength of cold-drawn wire. For alloy-steel bars, 70 per cent. of the strength or 85 per cent. of the 0·2-per cent. proof stress (whichever is less) is recommended, the proof stress being based on the smallest cross section of the bar. When alloy-steel bars are used in the pre-tensioned method, the recommended stress is increased to 75 per cent. of the strength or 90 per cent. of the 0·2-per cent. proof stress, whichever is the less.

The maximum tensioning stress given in the U.S.A. Recommendations is 70 per cent. of the strength; a stress of 80 per cent. is permitted for a short period provided that this stress is reduced to 70 per cent. when the tensioning operation is completed. The effective stress in the steel after losses have been deducted should in no case be assumed to exceed 60 per cent. of the strength or 80 per cent. of the yield stress or proof stress.

Stress due to Bending Permissible in Steel at Load Causing Failure.

The greatest stress in pre-tensioned steel recommended in the Code is equal to the tensile strength, except when the ratio of the tensile strength of the steel to the strength of the concrete multiplied by the percentage of reinforcement is very high. If the depth of the compression zone exceeds 60 per cent. of the effective depth to the steel, the permissible maximum stress is slightly less than the tensile strength. The maximum permissible stress for well-bonded post-tensioned steel is between 75 per cent. and 100 per cent. of the tensile strength, the lower stresses corresponding to higher values of the strength-percentage ratio and to greater depths of the compressive zone. With non-bonded post-tensioned steel it is advisable for the greatest stress to be the same as the initial tensioning stress. The greatest stress in non-tensioned steel should be equal to the yield stress or, in the case of high-strength steel, equal to the 0·2-per cent. proof stress.

In the U.S.A. Recommendations, formulæ are given in which a nominal tensile stress is used, which is equal to $\left(1-\frac{p.t_u}{2f_c'}\right)t_u$, in which t_u is the tensile strength of the steel and f'_c is the crushing strength of concrete cylinders. For example, if $t_u = 200{,}000$ lb. per square inch and $p = 1$ per cent., the permissible stresses corresponding to $f'_c = 5000$ lb. and 10,000 lb. per square inch are $0{\cdot}8\ t_u$ and $0{\cdot}9\ t_u$ respectively. Only mild steel may be used as non-tensioned reinforcement, and the greatest permissible stress is therefore the yield-point stress.

In the German Recommendations the greatest permissible stress is specified as the yield stress or proof stress for high-tensile steel because definite yielding occurs in most German wire when the proof stress is exceeded. If non-tensioned steel is used, it must be of a type normally used in reinforced concrete; the yield-points or proof stresses for the three types so used are 31,000 lb. per square inch (mild steel), 48,000 lb. per square inch, and 57,000 lb. per square inch.

The use of high-tensile steel for non-tensioned reinforcement is in accordance only with the recommendations of the new Code, and the greatest stress permissible in such reinforcement may be up to 90 per cent. of the tensile strength, if the 0·2-per cent. proof stress is 90 per cent. of the strength.

Permissible Stresses in Reinforcement Resisting Shearing.

No specific recommendations concerning tensile stresses permissible in shearing reinforcement at working load are given in the Code or the U.S.A. Recommendations, but it is recommended in the Code that the greatest tensile stress be 80 per cent. of the yield-point or the 0·2-per cent. proof stress. This recommendation implies that non-tensioned high-tensile steel may be used as shearing reinforcement.

The German Recommendations specify that the greatest stresses shall be the same as those due to bending, that is, 31,000 lb., 48,000 lb. or 57,000 lb. per square inch.

Stresses Permissible in Composite Members.

No recommendations or requirements for composite members are given in the U.S.A. Recommendations or the German Recommendations. In the Code it is stated that prestressed beams may be considered to act in conjunction with concrete cast in place if provision is made to resist the horizontal shearing forces at the surface of contact by the use of "shear connectors", or by means of roughening or irregularities of the surface of the concrete. Composite members may therefore be considered to behave as homogeneous members. The Code is the first document to recognise this behaviour, which has been proved by numerous tests, and to recommend tensile stresses in the concrete cast in place. The recommended stresses are only small, but in practice the concrete cast in place is prevented from cracking (except for harmless microscopic cracks) by the restraining effect of the adjacent compressed concrete.

In accordance with the Code, if the greatest working load is of frequent occurrence and of long duration (Case A) the tensile stresses f_{3w} in the added concrete cast in place (*Fig.* 2) vary from 200 lb. per square inch, for concrete having a strength of 3000 lb. per square inch, to 300 lb. per square inch when the strength is 6000 lb. per square inch. The corresponding stresses when the maximum load occurs rarely and is of short duration, as in the case of wind and snow on roofs (Case B), are 300 lb. and 450 lb. per square inch. These stresses are given in *Table* I. The stresses in the concrete cast in place may be increased by 50 per cent. if the stresses f_{1w} (*Fig.* 2) are reduced by the same numerical amount. For example, for concrete having a strength of 6000 lb. per square inch, prestressed by means of pre-tensioned steel, and subjected to sustained

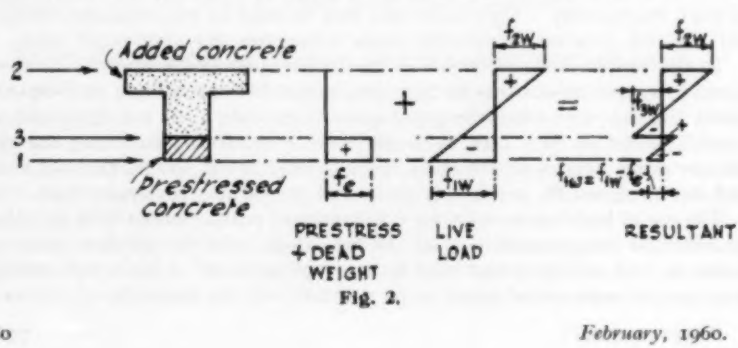


Fig. 2.

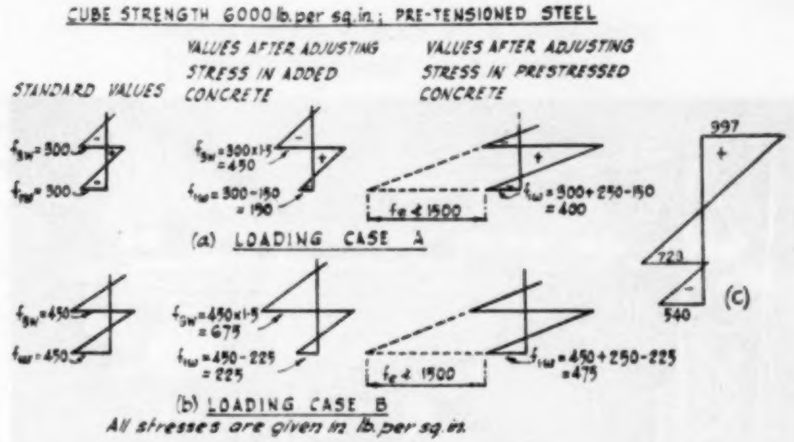


Fig. 3.

maximum loading (Case A), the tensile stresses recommended are 300 lb. per square inch in the prestressed concrete and in the concrete cast in place (*Fig.* 3a). If the stress in the concrete cast in place is increased by 50 per cent. to 450 lb. per square inch, the stress permissible in the prestressed concrete must be reduced by the same amount, that is to 150 lb. per square inch. If tests show that the increased tensile stress (that is $300 + 250 = 550$ lb. per square inch) does not exceed 75 per cent. of the stress at which the first crack appears, the stress permissible in the prestressed concrete would then become $550 - 150 = 400$ lb. per square inch. Stress-diagrams for these conditions are given in *Fig.* 3a. Similar diagrams for the case of temporary and rare loading (Case B) are given in *Fig.* 3b.

Many tests have shown that there are no harmful effects if much greater tensile stresses occur in the concrete, and several structures designed on the basis of these higher stresses are now in satisfactory service.[7] In *Fig.* 3c is shown the calculated distribution of stress for a road bridge designed by British Railways (Eastern Region), which has been in use since 1950. The limiting stress for loading of this type (Case A) is given in the Code as 450 lb. per square inch, yet the design stress of 720 lb. per square inch has proved to be satisfactory for this structure.

7.—R. E. Sadler. "Development in Overhead Electrification of Railways as it affects the Civil Engineer." Proc. Inst. Civil Engs., February, 1959.

Long Prestressed Lightweight Beams.

FOUR prestressed beams for the roofs of an auditorium and gymnasium at a school in northern California are each 98 ft. long and of tee-section 5 ft. 3 in. deep. The beams, which were cast at the works of the Basalt Rock Company, Inc., are of lightweight concrete made with expanded-shale aggregate. Each beam, which contains 32½ cu. yd. of concrete and weighs 50 tons, is prestressed with nine post-tensioned cables each comprising twelve 0·276-in. wires. The initial compression was 935,000 lb. on each beam and the working force assumed was 774,000 lb. The crushing strength of the concrete is 5000 lb. per square inch.

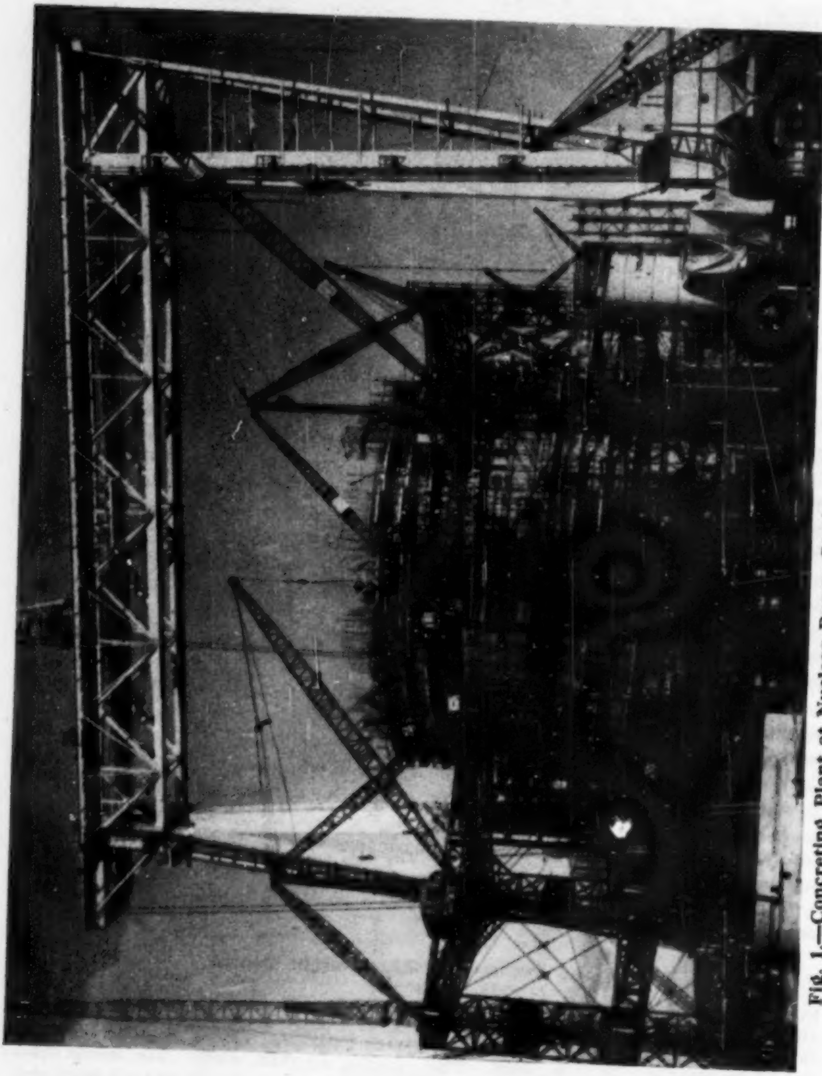


Fig. 1.—Concreting Plant at Nuclear Power Station: The Gantry Crane. *(See page facing.)*

Concreting Plant at a Nuclear Power Station in Scotland.

In *Fig.* 2 is shown the arrangement of the principal constructional plant at the site of the nuclear power station at Hunterston, Ayrshire. The largest permanent structures are the two reactor buildings (A) and (B) which are 200 ft. high, and the turbine hall (C) which is 672 ft. long, 125 ft. wide, and 58 ft. high and has a basement 11 ft. deep. There are numerous ancillary structures but the general arrangement of the plant is controlled by these large structures and the fabrication on the site of a steel spherical pressure vessel of 70 ft. diameter for each reactor. There are also, at each reactor, eight heat-exchangers in the form of steel cylinders 73 ft. 6 in. high and 19 ft. 6 in. diameter and each weighing about 200 tons.

Cranes.

A 300-tons crane (D), which is installed principally for the erection of the pressure vessels and heat-exchangers, makes it possible to use precast concrete beams weighing up to 300 tons in the upper part of the reactors. The gantry has a span of 208 ft. and the height to the underside of the main girder is about 200 ft.; it can straddle a reactor structure completely (*Fig.* 1). The crane travels on rail-tracks [(E) and (F) in *Fig.* 2] from the mechanical engineering workshop and fabrication area, and has subsidiary lifting-gears of 30 tons and 5 tons capacity.

Smaller loads, such as skips of concrete, reinforcement, and shuttering, are lifted by 7-tons derrick cranes [(G) in *Fig.* 2] four of which are provided around each reactor structure (*Fig.* 1). The cranes have 120-ft. jibs and are on triple steel towers 80 ft. high.

The basement of the turbine hall (*Fig.* 3) is of reinforced concrete and is served by derrick cranes travelling on rail-tracks, one track being on the floor of the basement and the other on the ground outside the basement walls. A 10-tons jib-crane travelling on two tracks on the floor of the basement is used mainly for the erection of the steel superstructure of the hall. There are also several cranes on road wheels or endless tracks. An electric lift is provided for men working on the reactors.

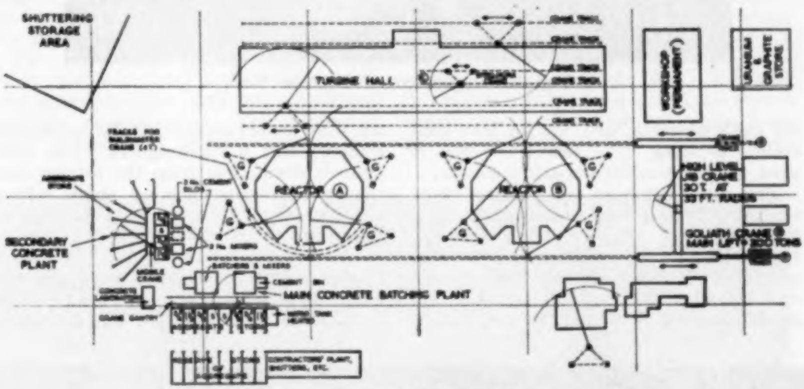


Fig. 2.—Arrangement of Plant.

Concrete Mixing Plants.

Concrete for the major part of the works is mixed at a main installation and at several secondary plants. Separate mixing plants are provided for outlying works such as the intake and culverts of the cooling-water system. The concrete includes three grades for reinforced concrete, one for prestressed concrete, three

Fig. 1.—Concreting Plant at Nuclear Power Station: The Gantry Crane. *(See page facing.)*

Fig. 3.—Basement of Turbine Hall.

for plain concrete, and one for lean concrete "blinding". A heavy concrete is used for the nuclear-radiation shields.

The main batching and mixing plant shown in *Fig.* 4 has a normal capacity of about 40 cu. yd. an hour. There are two batching and mixing installations, one of which comprises two drum-mixers of 1 cu. yd. capacity, and the other one similar mixer. The mixers are within the steel towers supporting the aggregate-hoppers and batch-weighers. The concrete is discharged from the mixers into tilting or bottom-opening skips, which are transported by lorries and transferred by cranes to the placing position.

The cement is delivered by rail to a station about three miles from the site and conveyed thence by road. (The installation at the station was described

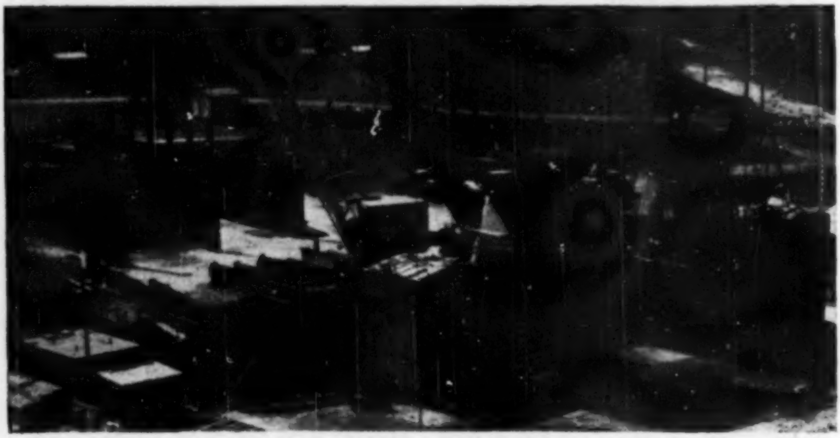


Fig. 4.—The Main Concrete Plant.

in this journal for January, 1959.) The cement is stored in rectangular steel bins, one of 60 tons capacity being provided at each installation, and is conveyed pneumatically, at a pressure not exceeding 15 lb. per square inch, to the batcher. The aggregates are delivered by road and stored in open compartments with concrete floors and dividing walls of timber sleepers. Two compartments are provided for sand and for each size of coarse aggregate, namely, ⅜ in., ¾ in., and 1½ in.; the total capacity is about 1500 tons. A reserve store with a capacity of about 10,000 tons is also provided. Two electric cranes and one steam locomotive-type grab crane travelling on a steel gantry between the batching plant and aggregates store deliver the aggregates into the hoppers of the batching plant. The coarse aggregate is crushed dolerite; the fine aggregate is sand.

The secondary mixing plant comprises two ½-cu. yd. drum-mixers, four steel aggregate bins, and two cylindrical portable cement silos. The aggregate store is arranged radially behind the mixers and has compartments for sand and ⅜-in., ¾-in., and 1½-in. crushed dolerite and for various sizes of iron ore (magnetite) for the high-density shielding concrete. The bins are filled by a drag-line bucket operated by a jib-crane on endless tracks. The aggregates are discharged into a batch-weigher which is slung from rails below the bins so that material from any bin can be discharged into any mixer. The concrete is discharged directly from the mixers into skips on lorries on a road under the mixing plant.

During cold weather hot air is blown on to the heaps of aggregates from portable air heaters fitted with flexible trunks. Also, steam is discharged into the middle of the heaps through perforated pipes and hoses connected to the boiler of a steam-crane. The mixing water is heated in two tanks each of 6000 gallons capacity provided with electrical elements in the base. By these means concrete has been mixed and placed when the air temperature has been 22 deg. F. without the temperature of

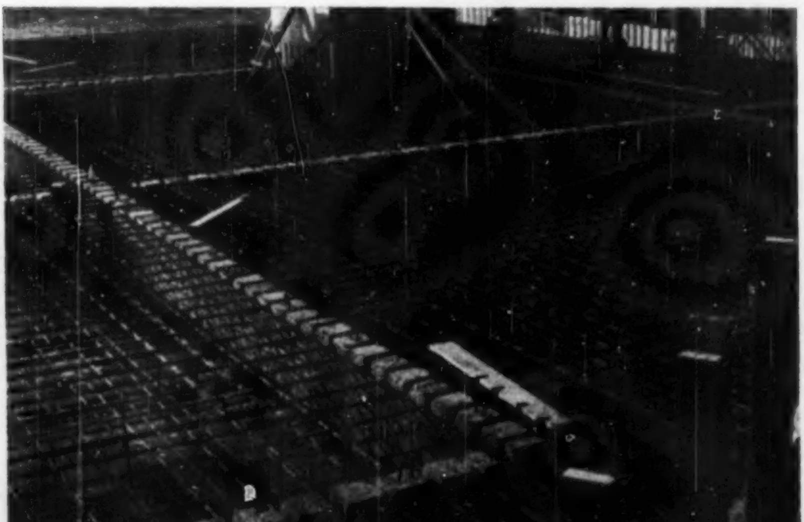


Fig. 5.—Raft Foundation of Reactor.

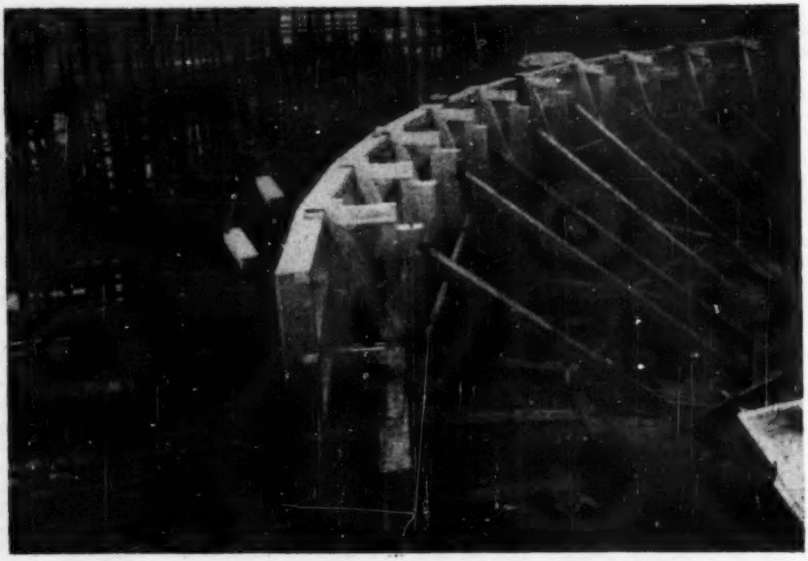


Fig. 6.—Shuttering for Circumferential Beam for Bottom Shield of Reactor.

Fig. 7.—Concreting the Bottom Shield of the Reactor.

the concrete falling below 40 deg. F. A laboratory is provided adjacent to the main mixing plant.

Rafts for Reactors.

The ground under the reactor structures, each of which weighs about 77,000 tons, is hard sandstone; the calculated imposed pressure is not more than 10 tons per square foot. The load is distributed by a reinforced concrete raft 7 ft. 6 in. thick, which was constructed in three horizontal layers. Each layer was cast in sections (*Fig.* 5) at the edges of which precast concrete stop-ends (*Fig.* 8) were provided. The stop-ends, which are left in position, are grooved across the top and bottom for the passage of the reinforcement bars. The faces are rebated and roughened to ensure a key with the concrete.

Bottom Shield of the Reactor.

The superstructure of each reactor structure comprises large reinforced columns supported on the raft and carrying the shield walls, the horizontal shields below and above the pressure vessel, and the building above the reactor for the service machine.

Eight interior columns support a circumferential beam 6 ft. 6 in. deep and stepped to provide a bearing for the bottom shield. The beam was cast in three layers; shuttering was provided for the full depth of the beam including the step (*Fig.* 6). The bottom shield is circular in plan, 54 ft. 3 in. in diameter and 6 ft. 6 in. thick. It is perforated by 101 openings through which the fuel-elements are passed into the pressure-vessel; the openings are formed by steel sleeves of about 2 ft. diameter embedded in the concrete, and the reinforcement bars in the shield pass between the sleeves.

In each shield there are 397 cu. yd. of concrete, with magnetite aggregate, having a density of not less than 210 lb. per cubic foot when dry; densities of about 220 lb. per cubic foot have been obtained. To avoid joints, which might decrease the efficiency of the shield, this concrete was placed continuously during 39 hours. Before concreting commenced the sleeves were secured to the bottom timber shutter by a cruciform jig and at the top by metal lugs welded to the reinforcement. Two prototypes of a part of the shield had been concreted to determine the best method of placing concrete as quickly as possible in a slab of such depth and complexity, and the method adopted was to mix and place the concrete by the usual means and compact it with immersion vibrators.

Fig. 8.—Precast Stop-ends at Construction Joints.

The bottom shield was cast after the walls of the reactor structure had been built to about 34 ft. above the shield to give sufficient working space. *Fig.* 7 shows the work ready for concreting. To avoid interruption in the continuity of casting, reserves of concrete were stored temporarily in four hoppers around the edge of the shield. Normally the concrete was discharged directly into position from each skip; the skips were lowered into the working space by one of the four derrick cranes.

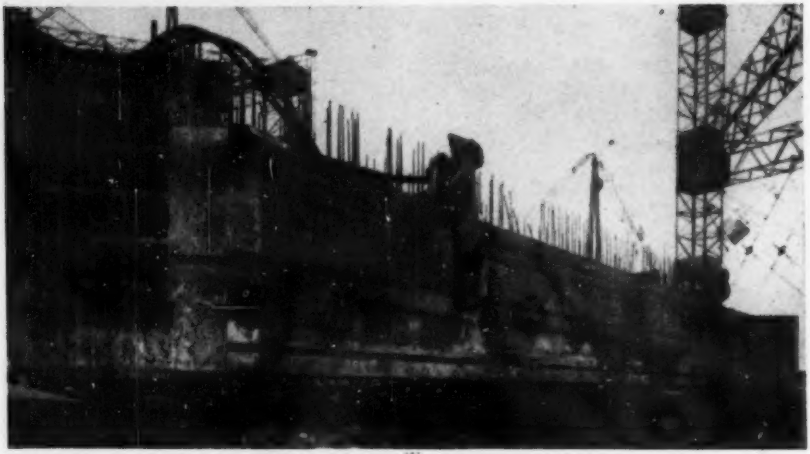


Fig. 9.—Precast Beam Weighing 250 tons.

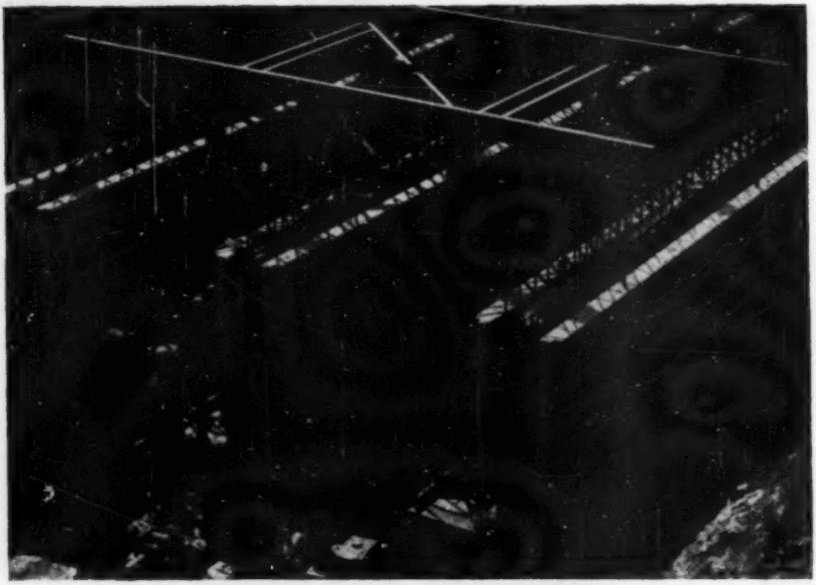


Fig. 10.—Travelling Shutter for Culvert.

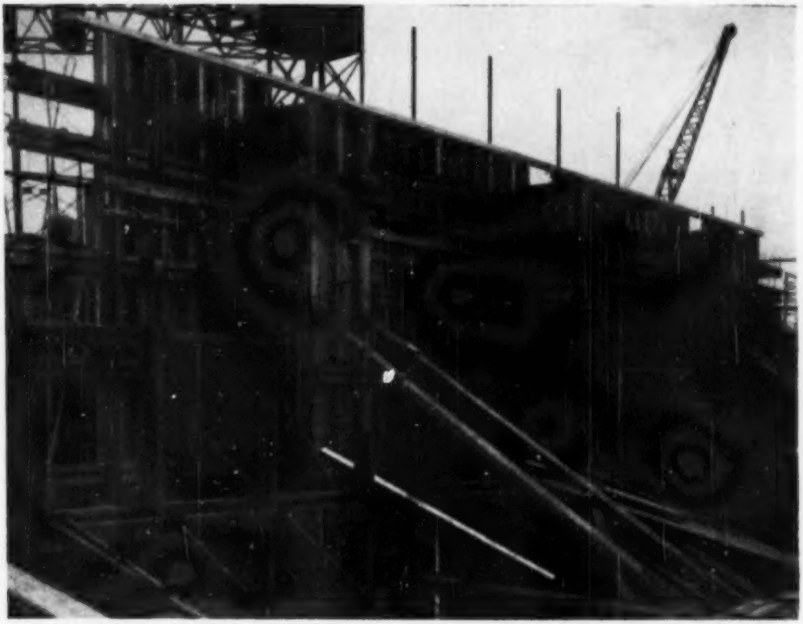


Fig. 11.—Shuttering for the Wall of the Basement of the Turbine Hall.

Shield Walls.

The shield walls of the reactors are of reinforced concrete; the inner wall is 5 ft. thick and the outer wall 4 ft. thick. Each wall is divided into eight parts separated by gaps 6 ft. wide. Each part was cast in 5-ft. lifts containing from 80 to 120 cu. yd. of concrete, all of which was placed in one working shift. In order to reduce shrinkage, sections diametrically opposite were concreted successively and the gaps between the sections were filled later.

The shutters for the walls were timber panels 11 ft. long and 5 ft. 6 in. deep made with sheets 6 ft. long and 2 ft. wide of plywood attached to a timber frame similar to those used for the walls of the basement of the turbine hall (*Fig.* 11) and elsewhere. Immediately after removal of the shuttering the concrete was sprayed with a curing compound; the compound discolours the concrete, but after about four weeks it begins to evaporate and eventually the concrete has its normal colour.

Precast Construction.

To enable the construction of the shield walls to proceed without interruption, precast floors are provided where it is convenient to do so. Sections of the floor slabs were cast in the yard between the reactors and lifted into position by the gantry crane.

The top shield over the pressure vessel is 10 ft. 6 in. thick and comprises precast members about 6 ft. 6 in. deep on which concrete is cast to a depth of 4 ft. By means of this construction heavy shuttering, at a great height and in a position where supports would be difficult, is unnecessary. The weight of some of the precast members exceeds 300 tons. *Fig.* 9 shows a beam of 250 tons ready for lifting by the gantry crane. The lifting tackle comprises wire-rope slings and steel shackles attached to mild steel shafts of 8-in. diameter cast in the beam. Each of the two slings on a beam is attached to one of the twin lifting-hooks of the gantry crane. The ends of these beams are prestressed by B.B.R.V. cables.

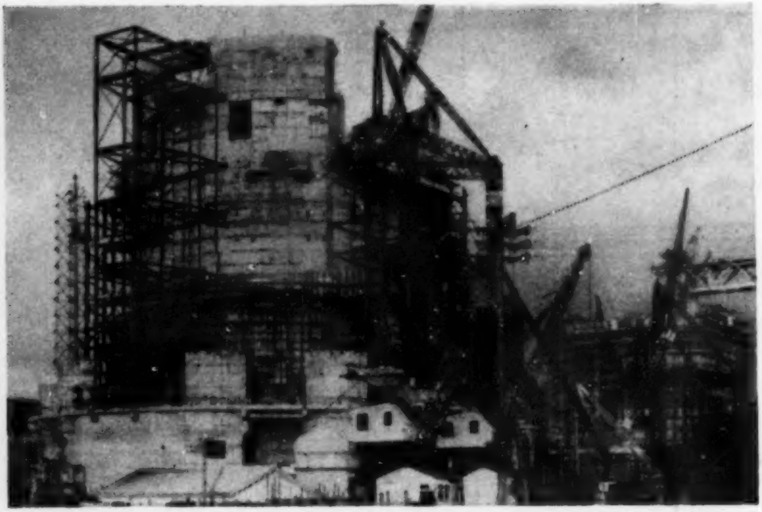


Fig. 12.

Culverts for Cooling-water.

When it is working at full capacity the station will require about 324,000 gallons of water to be circulated per minute. The water will be taken from the Firth of Clyde about half a mile south of the station and flow through culverts to ducts in the turbine hall. After circulating through the plant the water will proceed through other culverts and be discharged into the Firth to the west of the station. The culverts and ducts are of reinforced concrete. The ducts are of rectangular cross section and were cast in lengths of about 40 ft. Rubber water-stops are provided at each joint. The pipes to and from the condensers were built in during concreting.

The culverts are also of rectangular cross section except for two tunnels, each of 11 ft. diameter and about 550 ft. long, from the intake works off-shore to the pump-house on the shore. The inlet and outlet headworks will be constructed with caissons, which are less liable to damage by heavy seas than are cofferdams. The outlet headworks are about 1100 ft. off-shore. A permanent reinforced concrete jetty about 400 ft. long has been constructed to enable road vehicles to reach the intake works.

The shuttering for the rectangular double culverts (*Fig.* 10) comprises timber panels suspended from a travelling gantry. Four trolleys, to which are attached wire ropes by which the panels are suspended, travel on the bottom flange of the steel cross-head of the gantry and enable the panels to be moved sideways. The cross-head is supported on two steel frames which are carried on bogies running on narrow-gauge tracks on the floor of the culverts. At each position of the gantry the three walls of the culvert can be concreted for a length of 40 ft.

The station is being constructed for the South of Scotland Electricity Board by the General Electric Co., Ltd. Messrs. Simon-Carves, Ltd., are responsible for the design and construction of the civil engineering and building works. The consulting engineers for the cooling-water system are Messrs. L. G. Mouchel & Partners. Messrs. Mowlem (Scotland), Ltd., are the main civil engineering sub-contractors. A photograph taken recently and showing the progress of the work on the reactors is reproduced in *Fig.* 12.

Nomograms for the Design of Beams and Slabs by the Load-factor Method.—I.

By J. C. STEEDMAN.

Rectangular Beams and Solid Slabs: Reinforcement in Tension Only.

THE nomograms on pages 92 to 96 apply to the design of solid slabs and rectangular beams, reinforced to resist tension only, in accordance with the load-factor method as recommended in British Standard Code No. 114 (1957). The accuracy of the results obtained by using the charts is generally sufficient for practical purposes and for checking designs. Separate charts apply to compressive stresses of 1000 lb., 1250 lb., and 1500 lb. per square inch in the concrete with tensile stresses of 20,000 lb. and 30,000 lb. per square inch in the reinforcement. The cross-sectional area of reinforcement required in a beam or slab of any effective depth can be determined for a wide range of applied bending moments. The symbols are as in the Code and the units are in pounds and inches. The bending moments and the area of the reinforcement are expressed in inch-pounds per inch width of beam and per foot width of slab. (Nomograms for a compressive stress of 1500 lb. per square inch will be given in a later number.)

The effective depth required to provide a moment of resistance of $\frac{p_{cb}}{4}.bd_1^2$ is obtained by direct reading. The effective depth provided should not be less than the depth required; otherwise the nomograms do not apply, as reinforcement in compression is required.

If the stresses in the concrete and reinforcement do not correspond with those in Nomograms Nos. 1 and 2, the percentage of reinforcement required for any ratio of stresses between 10 and 30 can be determined from Nomogram No. 3. The basic formula from which Nomograms Nos. 1 and 2 are derived is

$$M = A_{st}p_{st}l_a, \text{ in which } l_a = d_1 - \frac{3A_{st}p_{st}}{4bp_{cb}}.$$

Substituting r = percentage of reinforcement $= \frac{100A_{st}}{bd_1}$ and R = ratio of permissible stresses $= \frac{p_{st}}{p_{cb}}$:

$$\frac{M}{bd_1^2p_{cb}} = \frac{Rr}{100}\left(1 - \frac{3Rr}{400}\right) \text{ and } l_a = \left(1 - \frac{3Rr}{400}\right)d_1,$$

which is the basis of Nomogram No. 3.

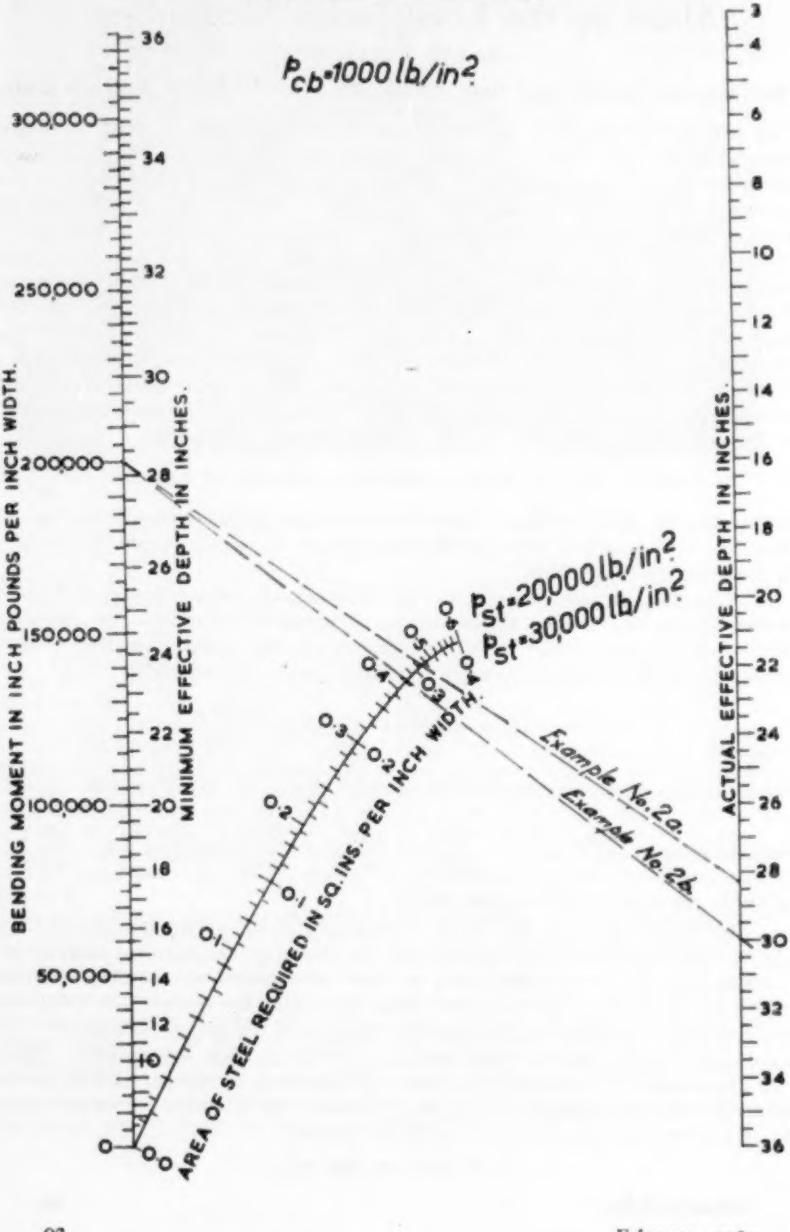
The method of using the charts is explained in the examples which follow. The operations required in each example are shown on the relevant nomogram.

EXAMPLE No. 1.—A solid slab 9 in. thick is subjected to a bending moment of 150,000 in.-lb. per foot of width. Make sure that the thickness is sufficient, and determine the area of reinforcement required if the permissible stresses are p_{cb} = 1000 lb. per square inch and p_{st} = 20,000 lb. per square inch. Since d = 9 in., with ¾-in. bars and ¾-in. cover of concrete d_1 = 7·87 in. From Nomogram No. 2A, minimum d_1 = 7·07 in.; therefore the thickness is satisfactory. A_{st} = 1·17 sq. in.; say, ¾-in. bars at 4½ in. centres.

(Continued on page 97.)

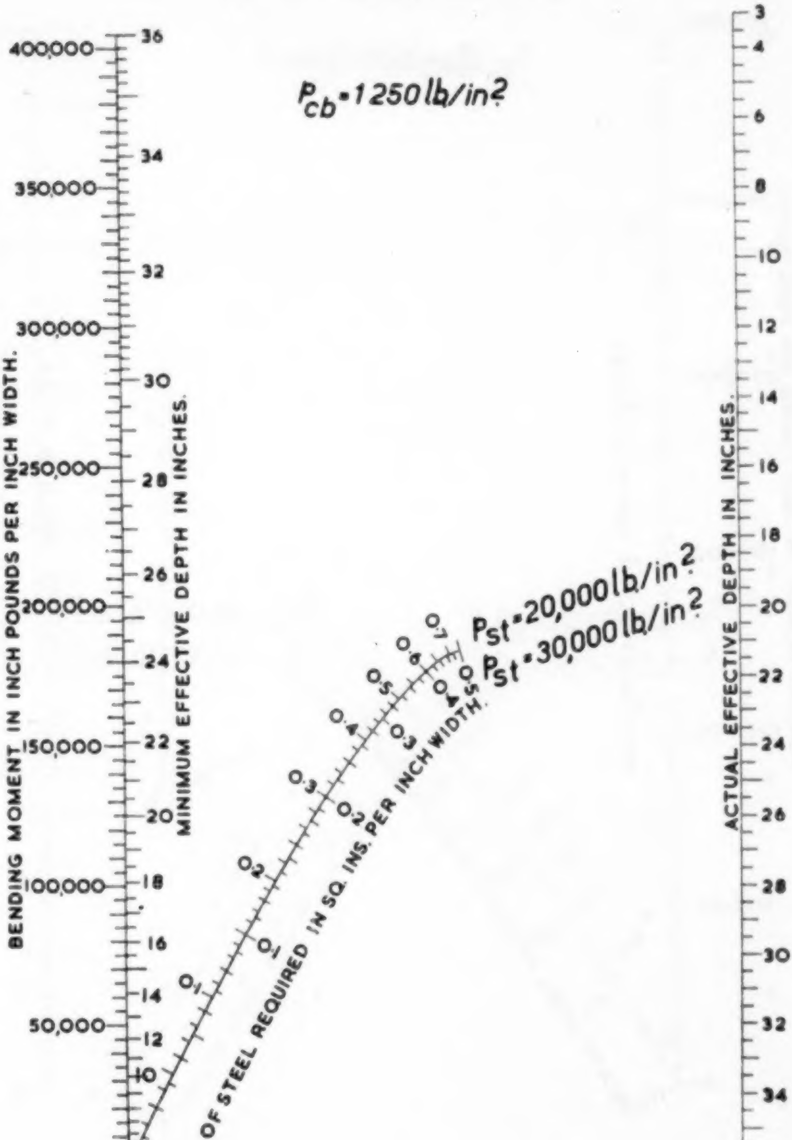
No. 1A.—DESIGN OF RECTANGULAR BEAMS BY THE LOAD-FACTOR METHOD.

Reinforcement in Tension Only.



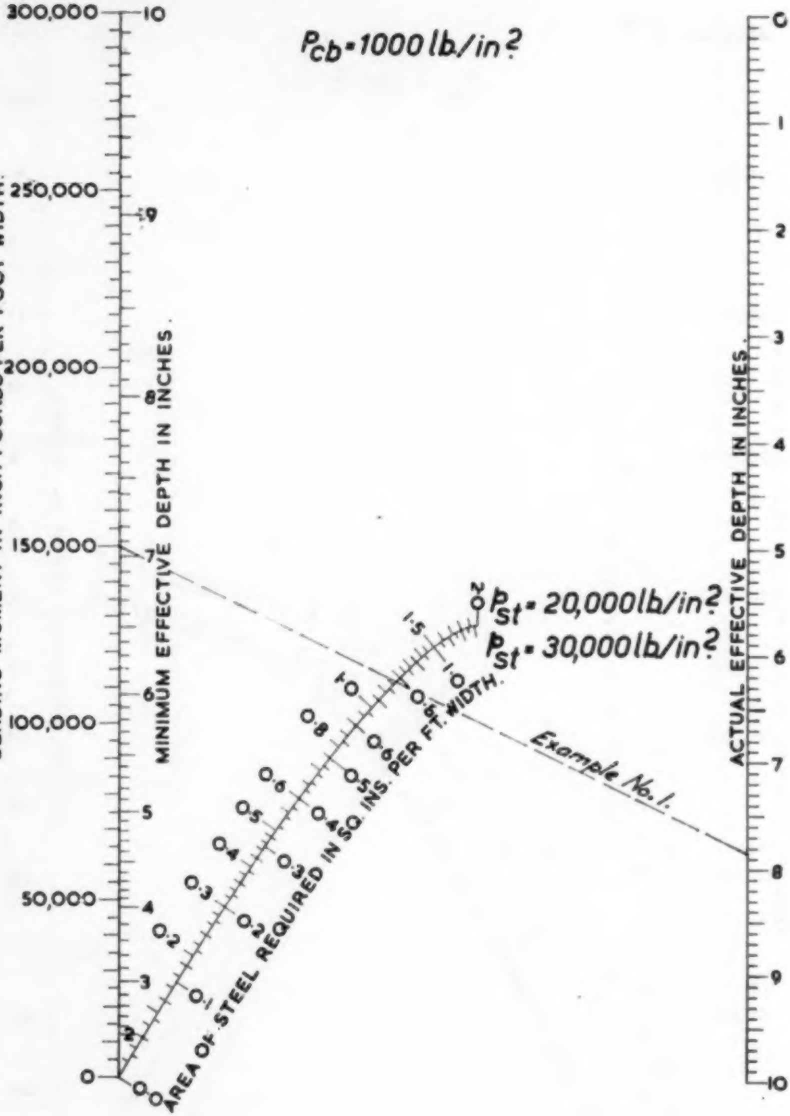
No. 1B.—DESIGN OF RECTANGULAR BEAMS BY THE LOAD-FACTOR METHOD.

Reinforcement in Tension Only.



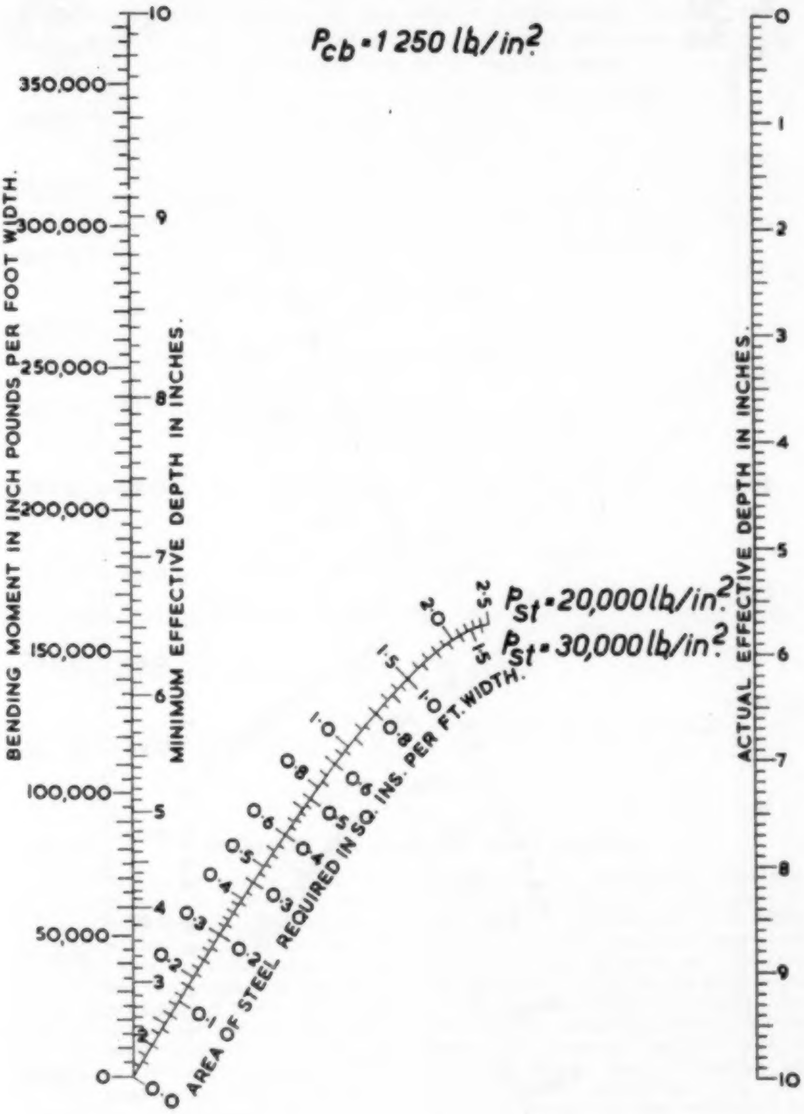
No. 2A.—DESIGN OF SOLID SLABS BY THE LOAD-FACTOR METHOD.

Reinforcement in Tension Only.

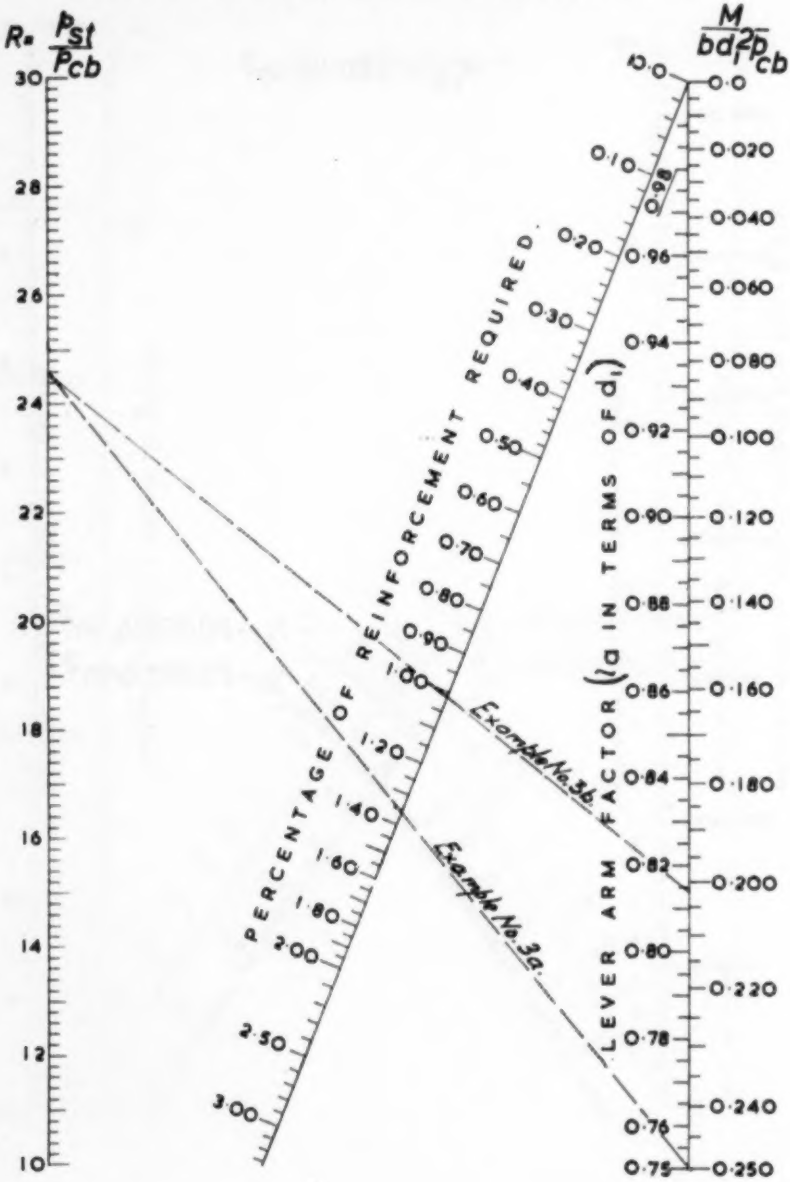


No. 28.—DESIGN OF SOLID SLABS BY THE LOAD-FACTOR METHOD.

Reinforcement in Tension Only.



No. 3.—DETERMINATION OF CONSTANTS FOR DESIGN OF RECTANGULAR BEAMS AND SOLID SLABS BY THE LOAD-FACTOR METHOD.



(*Continued from page 91.*)

EXAMPLE No. 2.—A rectangular beam 9 in. wide is subjected to a bending moment of 1,800,000 in.-lb. Determine (a) the minimum effective depth and area of reinforcement required; (b) the area of reinforcement required if the effective depth is 30 in. Permissible stresses are 1000 lb. per square inch in the concrete and 30,000 lb. per square inch in the reinforcement.

$$M = 1{,}800{,}000 \div 9 = 200{,}000 \text{ in.-lb. per inch of width.}$$

(a) From Nomogram No. 1A, minimum $d_1 = 28{\cdot}3$ in.

$$A_{st} = 0{\cdot}314 \times 9 = 2{\cdot}83 \text{ sq. in.}$$

(b) Also from Nomogram No. 1A, if $d_1 = 30$ in. $A_{st} = 0{\cdot}281 \times 9 = 2{\cdot}53$ sq. in.

EXAMPLE No. 3.—Solve the problem in Example No. 2 if the stresses are $p_{cb} = 1100$ lb. per square inch and $p_{st} = 27{,}000$ lb. per square inch.

$$R = \frac{27{,}000}{1100} = 24{\cdot}54.$$

(a) With minimum d_1, $\dfrac{M}{bd_1^2p_{cb}} = 0{\cdot}25$; therefore

$$d_1 = \sqrt{\frac{1{,}800{,}000}{1100 \times 0{\cdot}25 \times 9}} = 27{\cdot}0 \text{ in.}$$

From Nomogram No. 3, $r = 1{\cdot}36$ per cent. $A_{st} = \dfrac{1{\cdot}36 \times 9 \times 27}{100} = 3{\cdot}30$ sq. in.

(b) If $d_1 = 30$ in., $\dfrac{M}{bd_1^2p_{cb}} = \dfrac{1{,}800{,}000}{30^2 \times 9 \times 1100} = 0{\cdot}202$,

and, from Nomogram No. 3, $r = 1{\cdot}01$ per cent. $A_{st} = \dfrac{9 \times 30 \times 1{\cdot}01}{100} = 2{\cdot}73$ sq. in.

Alternatively by calculation, with $\dfrac{M}{bd_1^2p_{cb}} = 0{\cdot}202$,

$$l_a = 0{\cdot}814d_1 . A_{st} = \frac{1{,}800{,}000}{27{,}000 \times 0{\cdot}814 \times 30} = 2{\cdot}73 \text{ sq. in. as before.}$$

(*To be concluded.*)

A Viaduct of Ten Spans in North London.

CONSTRUCTION has started of a new viaduct of ten spans to replace the existing Angel Road bridge over the railway at Edmonton, Middlesex. The load on the old bridge, which was the subject of the abstract from this journal of fifty years ago in our number for March, 1959, was restricted to 30 tons, but the new structure has been designed to carry the Ministry of Transport loading. There are to be two carriageways each 30 ft. wide and two footpaths each 10 ft. wide. The total length including the approaches will be 2550 ft. The viaduct will have five spans of 40 ft. each, four spans of 50 ft., and one span of 57 ft. 6 in. The construction will comprise prestressed concrete beams supported on reinforced concrete piers. A subway for pedestrians will be provided under the eastern approach. The consulting engineer to the Ministry of Transport for this work is Mr. John Mason. The contractors are Messrs. Leonard Fairclough, Ltd. The cost of the bridge and road works will be about £370,000.

The Late Mr. Arthur W. Legat.

THE death occurred in December last of Mr. Arthur Watson Legat, a former partner in the consulting engineering firm of Messrs. F. A. Macdonald & Partners, Glasgow. Mr. Legat, who was in his sixty-sixth year, was a member of the Institution of Civil Engineers and joint author with Mr. G. Dunn and Mr. W. A. Fairhurst of the book entitled "Design and Construction of Reinforced Concrete Bridges".

MR. W. A. FAIRHURST writes as follows: "Mr. Legat served his apprenticeship with a London firm of civil engineers specialising in harbour works. After service in the First World War he was employed by what is now Truscon, Ltd., and later was in charge of the drawing office of the reinforced concrete department of Sir William Arrol & Co., Ltd., at Glasgow. At the end of 1923 he was appointed chief engineer of the British Reinforced Concrete Engineering Co., Ltd., then at Manchester, and moved with this company to Stafford in 1926, where he remained until the end of 1928. Mr. Legat joined Messrs. F. A. Macdonald & Partners, as a partner, in January 1929, and during the next ten years was engaged in the design and supervision of many types of reinforced concrete and civil engineering works. He was instrumental in securing for the firm the design of many bridges in Scotland, including Inverbervie Bridge (Kincardineshire), Glen Bridge (Dunfermline), a bridge at Guardbridge (Fife), and a bridge over the River Dee at Aboyne (Aberdeenshire). Collaboration with his partner, Mr. George Dunn, resulted in the design and construction of a number of fine bridges. He was a very popular figure in engineering circles throughout Scotland and by numerous lectures and articles did much to advance reinforced concrete construction."

MR. A. P. MASON writes as follows: "Mr. Legat was a man of great ambitions and a first-class engineer who attacked his work with unbounded energy and inspired all those who worked with him. His appointment to the British Reinforced Concrete Engineering Co., Ltd., was like a fresh breeze, and he devoted himself to laying the foundations of a great design organisation. Although it is a long time since he left the Company, his name remains fresh among the older members of the staff, who held him in the highest esteem."

A Prismatic-slab Foundation Raft.

THE economy of providing a raft foundation in the form of a number of sloping and horizontal slabs (*Fig.* 1) is described by Mr. I. Martin and Mr. S. Ruiz in the Journal of the American Concrete Institute for August 1959. The foundation is for a building in Havana having twenty-four stories and a height above the foundation of 308 ft. The building is designed to resist a wind pressure of 60 lb. per square foot owing to the prevalence of hurricanes. The ground comprises a superficial layer of non-homogeneous marl overlying a mixture of clay and silt on which the raft is founded. The safe bearing pressure is 6000 lb. per square foot. The raft is designed as a prismatic (folded-plate) structure.

The quantities of materials in the raft as constructed and in a raft of conventional planar slab-and-beam construction are as follows.

	As constructed.	Alternative.
Excavation (cu. yd.)	11,510	8764
Concrete (cu. yd)	2610	4159
Reinforcement (tons)	281	370
Shuttering (sq. yd.)	3754	7436
Earth filling (cu. yd.)	1177	nil

The saving in cost, at prices prevailing in Havana, was 30 per cent., and it is estimated that a saving of about 20 per cent. would be made for a similar foundation at current British prices.

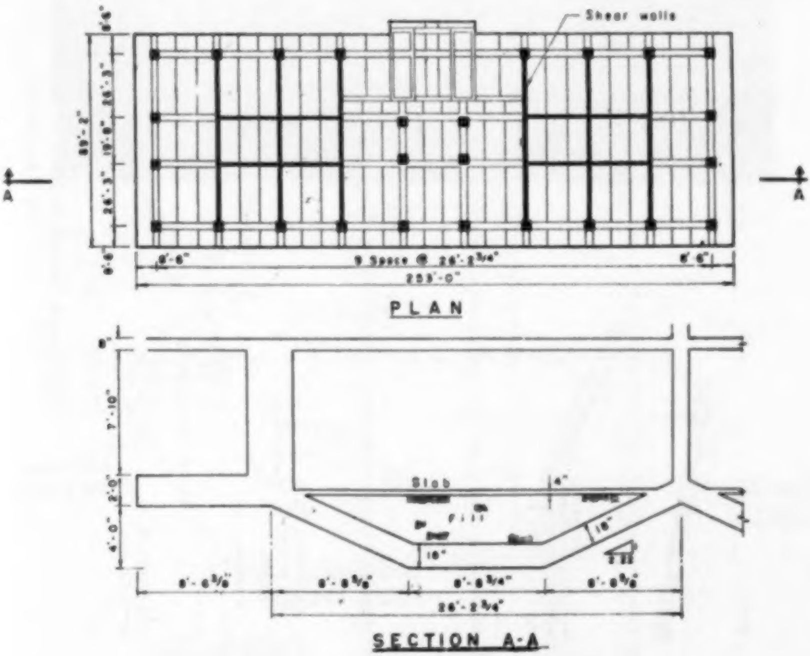


Fig. 1.

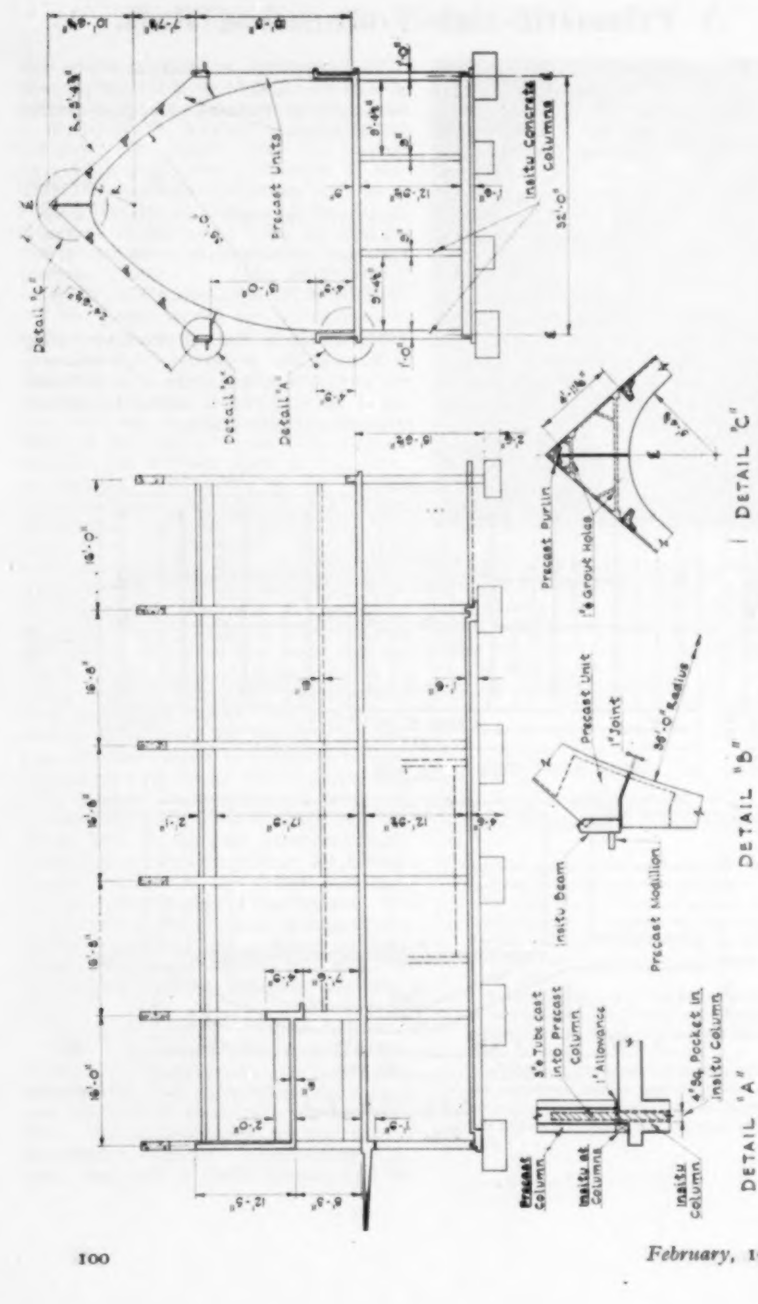


Fig. 3.—A Chapel at Oxford: Sections and Details.
(See page facing.)

A Chapel at an Oxford College.

The Chapel of Westminster College, Oxford, has a precast concrete frame and brick walls, and is above the library which has frames and floors of concrete cast in place. Longitudinal and transverse sections of the structure are given in *Fig.* 1. The six frames of the chapel (*Fig.* 4) are parabolic arches, each of which was precast in four parts, namely, the two columns up to the eaves and the two rafters. The arches are hinged at the floor of the chapel but rigid joints are provided at the eaves and at the ridge.

The columns were erected first (*Fig.* 2), and bars projecting therefrom are supplemented by reinforcement placed in slots formed in the member (*Fig.* 3) and concreted to provide a rigid joint. The members are bolted together at the ridge, the bolts passing through holes formed

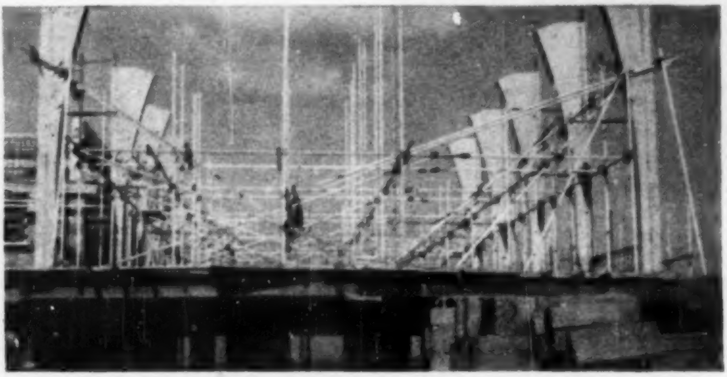


Fig. 2.

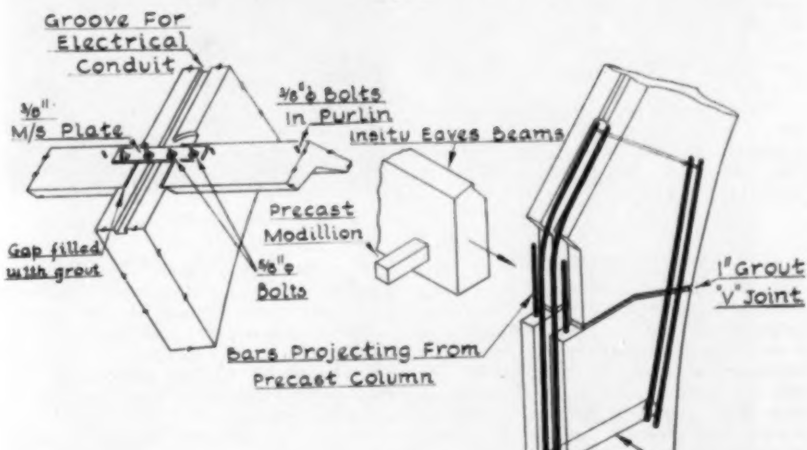


Fig. 3.—Joints at Eaves and Purlins.

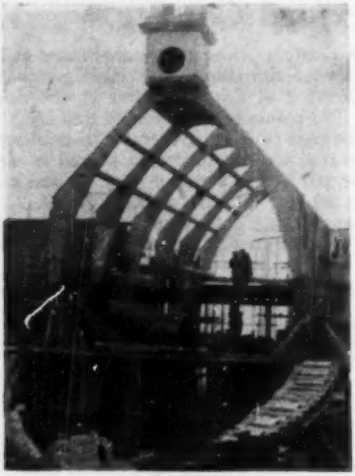


Fig. 4.

in the rafters. The bolts are grouted in position. Precast purlins are bolted to the frames at about 6 ft. centres.

At one end of the chapel the shape of the arches at the ridge varies to provide a platform supporting a wooden belfry. At the same end an organ-loft of concrete cast in place is provided. Access to the chapel is by means of two curved stairs (*Fig.* 4) which are of concrete cast in place. The chapel is one of several new buildings for the college.

The architects are Lord Mottistone and Mr. P. E. Paget and the consulting engineers are Messrs. Hajnal & Myers. The contractors were Messrs. Marshall Andrew & Co., Ltd.

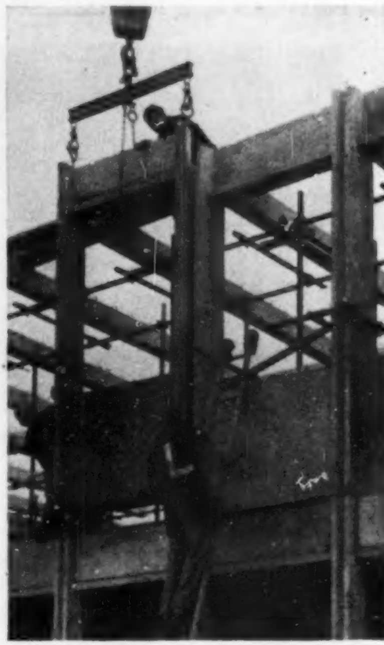
Tenders for Bridges.

THE Minister of Transport announced recently that a new basis of tendering for large bridges is to be introduced. It is intended that, for schemes in which the requirements might be met equally by two or more types of structure, such as a steel bridge, a suspension bridge, a reinforced concrete bridge, or a prestressed concrete bridge, the tenders submitted may be based on désigns prepared by or on behalf of the contractors.

Precast Wall Slabs.

THE illustration shows the erection of precast wall slabs at a two-story building at Mill Hill, London, with a floor area of 25,000 sq. ft. The superstructure was completed in seventeen weeks.

The frames, of which there are 258, are of story height and comprise the mullions between the windows, a lintel, and a wall slab below each window. The exposed-aggregate slabs are alternately light and dark, the face of those of the lighter colour being smooth and those of the darker colour being rough. The columns are formed by casting concrete in the cavities between the vertical members of adjacent frames.



Fixing Slabs in Precast Frames.

The system of construction is called "Laingwall" and the building is for the use of the contractors, Messrs. John Laing & Son, Ltd.

Mesh Reinforcement for Doubly-curved Slabs.

Mr. Herbert Z. Littman, of Tel-Aviv, has sent us the following description of a welded mesh devised for the reinforcement in three directions of doubly-curved slabs.

It is preferable for the reinforcement bars in a doubly-curved concrete slab, such as a dome, to be in three directions each mutually at an angle of 60 deg., as thereby the tensile forces are transferred directly to the reinforcement and consequently a thinner slab may be used and the risk of cracks is reduced. Attempts to make a welded mesh with three layers of bars each mutually at an angle of 60 deg. have not been successful owing to practical difficulties arising during welding where three bars cross at the same place. If the bars were arranged not to cross in this manner it would be necessary to have a special machine, the bars in the central layer would have to be crimped, and the resulting mesh would be too rigid to place correctly on a doubly-curved surface.

A satisfactory solution is to provide two sheets of welded mesh each containing bars in two directions at 60 deg. The sheets are laid one above the other. In the bottom sheet the lower bars provide the full cross-sectional area required in one direction, and the upper bars provide half the cross-sectional area required in the central layer in one of the two remaining directions. The top sheet is identical with the bottom sheet but is inverted and placed with the lower bars in the same direction as the upper bars in the bottom sheet, thereby providing the remaining half of the cross-sectional area required in the central layer and the upper bars provide the full cross-sectional area required in the top layer in the third direction.

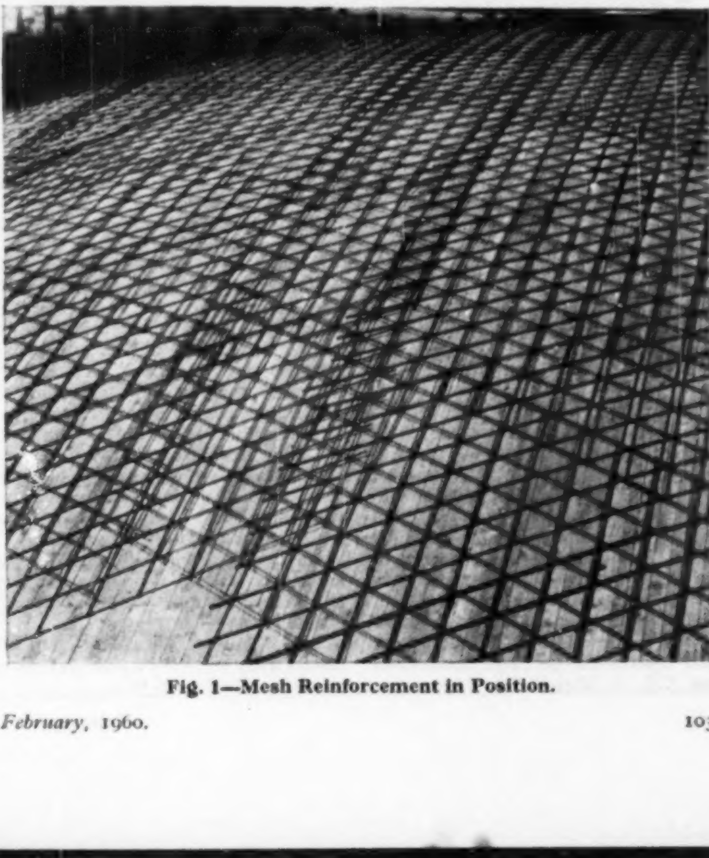


Fig. 1—Mesh Reinforcement in Position.

The sheets are laid one upon the other in such a way that the bars in the central layer are in the same direction. The sheets are placed so that the overlaps at the boundaries of the top sheet do not coincide with those in the bottom sheet. It is claimed that 1000 square metres (1196 sq. yd.) of two layers of sheets can be laid in six man-days. The illustration (*Fig.* 1) shows the reinforcement in place.

The sheets are sufficiently elastic to conform to most curved surfaces. The radius of the dome in which the reinforcement was first used is 15 m. (46 ft. 9 in.). The bars in the top and bottom layers are 8 mm. diameter (0·315 in.), and in the central layer 5·7 mm. (0·224 in.). The bars, which were twisted cold, are spaced at 25 cm. (10 in.) centres. The cost of converting an existing spot-welding machine is comparatively small. Tests * show that the welds are as sound as welds at the intersection of the wires in ordinary steel fabric and that the welding does not affect the yield stress of the twisted bars.

This reinforcement was developed by Mr. Littman of Reshet Sigma, Ltd., for use in a number of domes in collaboration with the structural engineers, Messrs. Ben-Zwi & Rochman, of Tel-Aviv. It is also used for a dome of 35 m. (115 ft.) radius at the main hall of the Tel-Aviv Jubilee Exhibition, which was constructed by Mr. Vardiman, of Tel-Aviv.

* See "Welding of Twisted Steel", by H. Z. Littman. Journal of the Association of Engineers and Architects in Israel, September 1958.

Prestressed Concrete Cylindrical Tanks.

MR. G. D. ALLISON, of Preload, Ltd., writes as follows.

In his paper "How Can the Advantages of Prestressed Concrete best be Utilised?", reported in your number for November 1959, Professor Rusch's observations on wire-wound cylindrical tanks convey an impression of a risk of corrosion which in fact need not exist. Professor Rusch does not mention the very important point that the protective cover of gunite should be allowed to harden while the tank is full, as stated in the article on page 12 of your number for January 1960, so that no tensile stress will develop in the gunite. Also, continuing creep of the prestressed concrete wall actually induces a small compressive stress, and the gunite effectively bonds and protects the wire.

Association for Shell Structures.

AN International Association for Shell Structures (IASS) was formed recently to aid the development of structural shell construction by means of meetings to facilitate interchange of ideas, and the publication of articles in technical journals. The Association intends to hold a colloquium on precast shells in the autumn of 1960 (at Warsaw or Dresden). Particulars of the Association are obtainable from the Secretariat of the International Association for Shell Structures, Alfonso XII, 3; Madrid (7), Spain.

Training Courses on Concrete.

THE number of training courses on concrete held at the research station of the Cement and Concrete Association at Wexham Springs, Bucks., is to be doubled in 1960 and include some sessions which previously had been held at intervals of two or three years. In addition to the usual courses there will be two sessions for architects, courses for farmers, estate managers and the like, on farm buildings, and two courses for builders. Two courses for engineers will deal with the design of prestressed and reinforced concrete bridges.

The provisional programme includes the following: February 15 to 19 and February 22 to 26, Design of prestressed and reinforced concrete bridges (for engineers). February 29 to March 4 and March 7 to 11, Concrete construction (for builders). March 14 to 18, Concrete construction for farms. March 21 to 25 and March 28 to April 1, Concrete and soil-cement roads (for supervisors). June 13 to 17, June 20 to 24, September 19 to 23, and September 26 to 30, Structural concrete (for engineers). June 27 to July 1, Soil-cement roads and airfields (for engineers). July 4 to 8, Concrete roads and airfields (for engineers). July 11 to 15 and July 18 to 22, Concrete for architects. From October 3 to December 9 there are nine courses on structural concrete (for supervisors).

Full details of the courses can be obtained from the Association, 52 Grosvenor Gardens, London, S.W.1.

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Deep Cylindrical Foundation Piers.

CYLINDRICAL foundation piers to carry loads up to 2000 tons at depths up to 80 ft. are being constructed for buildings in London and elsewhere by means of the plant shown in the illustrations. The procedure is to bore a hole to the required depth by means of an auger and to fill the hole with concrete. The auger (*Fig.* 1) is from 3 ft. to 7 ft. in diameter and is attached to the end of a vertical hollow square steel shaft which is suspended from the crane jib of an ordinary heavy excavating machine. A cantilevered member carrying the guide and rotating mechanism for the shaft is fixed to the excavator, the motor or engine and winches of which provide the power and motions for the shaft and auger. The advantages of using an excavator are that the boring device is mobile, that a standard machine can be adapted, and that when it is not used for boring it can be readily converted for use as a crane or excavator.

The auger is worked into the ground by screw-action aided by the weight of the shaft. In very hard ground the sinking can be assisted by an hydraulic jacking device attached to the guide. The length of the shaft, within which is another shaft, is about 50 ft. When the hole has been bored to this depth the inner shaft comes into operation automatically and boring proceeds to the depth required. The helical blade of the auger comprises about two complete turns. The auger rotates clockwise when boring and after each downward travel equal to about the length of the auger the rotation is stopped and the auger is brought to the surface (*Fig.* 1), the jib is swung round and, by an anti-clockwise rotation of the shaft and auger, the excavated soil on the screw is flung off. The jib is then swung back and the auger is lowered into the bore to make a further cut.

If the area at the base of the pier is required to be greater than that of the hole excavated by the auger, a device (*Fig.* 2) comprising cutters projecting from a steel cylinder is lowered to the bottom of the bore and rotated. The link-motion to which the cutters are attached causes them to extend progressively farther out of the cylinder as the

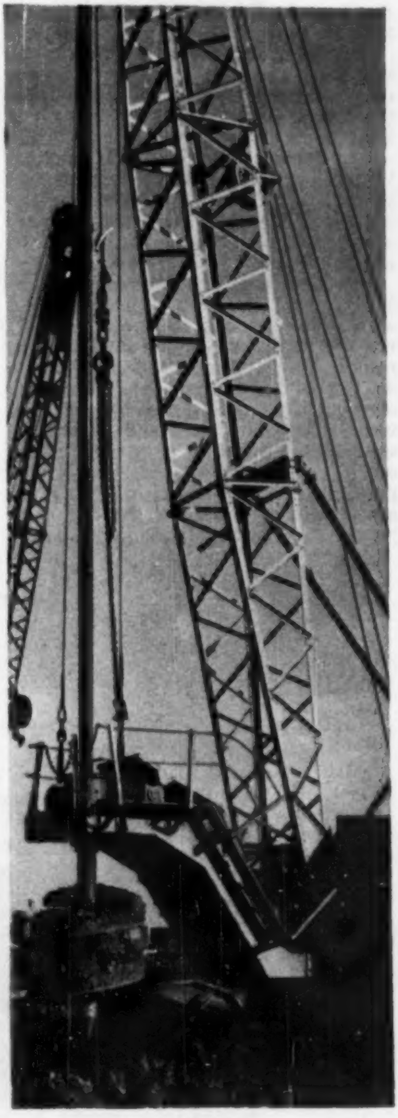


Fig. 1.

side of the bore is excavated so that an enlarged cavity is formed in the ground. The diameter of the cavity is about twice that of the auger, and the diameter of the largest cavity which can be formed is about 15 ft.

The bore, and the cavity (if any) at the base, are filled either by dropping concrete through a sheet-metal funnel at the top of the bore or by lowering it in bottom-opening skips. It is claimed that a well-consolidated concrete is produced by the former method due to the impact of the falling material, which has a slump not exceeding 3 in. Immersion vibrators are used to compact the concrete in the upper part of the pier.

The method is most suitable for piers in clay, in which case boring may proceed at a rate exceeding 20 ft. per hour. If the top strata are loose a steel lining is sunk as boring proceeds and is withdrawn as the concrete is placed. The load-carrying capacity of the piers depends on bearing at the bottom and friction on the sides. Most of the piers so far driven are in firm clay for a considerable proportion of their depth; this has the advantages of increasing the area subjected to frictional resistance and of

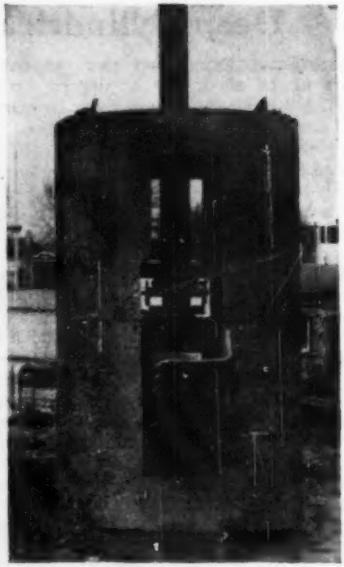


Fig. 2.

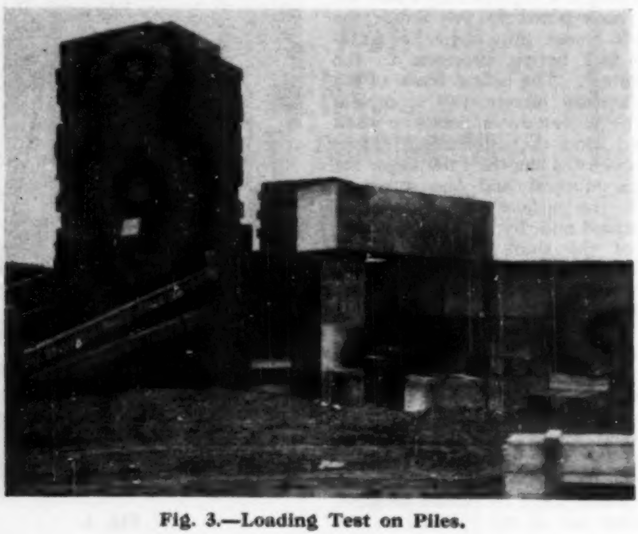


Fig. 3.—Loading Test on Piles.

bearing on confined clay which is likely to have a greater resistance than clay nearer the surface.

This method of constructing cylindrical piers was developed in Great Britain by Economic Foundations, Ltd., and among the foundations constructed by this means are about 150 piers of 4 ft. 6 in. and 7 ft. diameter 70 ft. deep, with enlarged bases, for the new building at South Bank, London, for the Shell Petroleum Co., Ltd. About three hundred foundations of this type are also provided for some of the structures adjacent to the reactors at the nuclear power station at Bradwell, Essex. These piers, the greatest load on which is 350 tons, penetrate 35 ft. of filling and brown clay and extend about 10 ft. into the underlying hard blue clay.

Tests.

Four piles of this type each of 3 ft. diameter were recently tested with loads up to 1000 tons. One pair extended to a depth of 55 ft. to clay having a shearing strength of 2½ tons per square foot, and the other pair extended to a depth of 40 ft. where the clay had a strength of 1½ tons per square foot. One pile in each pair was the same diameter throughout, but on the other an expanded foot of 7 ft. diameter was formed. Each of the plain piles contained near the bottom a compressible layer which would transfer appreciable load to the bottom of the pile only after the frictional resistance on the sides had broken down; by this means the frictional resistance and the bearing resistance could be determined separately. The testing rig is shown in *Fig.* 3. The load was imposed by hydraulic jacks coupled together. The forces imposed by the jacks were measured by four 250-tons electrically-balanced pressure cells, which were made specially for this test. The results of the tests confirmed that the calculated loads were safe. The tests were carried out under the supervision of Messrs. R. H. Harry Stanger.

Lectures on Building.

THE following lectures have been arranged by the Ministry of Works. Admission is free.

Building High, by N. Wakefield at the Technical College, Cambridge; February 15, 7.30 p.m.

Thermal Insulation of Buildings, by N. Foster at the Grosvenor Museum, Chester; February 15, 7.15 p.m.: and by R. R. Houston at the College of Technology, Portsmouth; February 25, 7.15 p.m.

The Builder and his Contract, by R. Proctor at the Technical College, York; February 16, 7.15 p.m.

Introduction to Programming and Progressing for Builders, by A. E. Chittenden at the Grand Hotel, Cardiff; February 17, 7.15 p.m.

Four New Techniques in Building, by D. Bishop at Willesden Technical College, London, N.W.10; February 17, 7.15 p.m.

Safety in the Building Industry, by J. A. Hayward at Hertfordshire College of Building, St. Albans; February 18, 7.15 p.m.

Dampness in Buildings, by W. A. Hammond at the Technical College, Carlisle; February 22, 7 p.m.

Settlement of Buildings, by S. R. Rosenak at S.E. London Technical College, London, S.E.26; February 22, 7.15 p.m.

Work Study in Building, by R. Geary at the Town Hall, Lancaster; February 24, 7.30 p.m.

R.I.B.A. Form of Contract, by I. N. D. Wallace at the City College, Norwich; February 24, 7.15 p.m.

Concrete Placing and Formwork, by A. B. Harman at the Technical College, Newport, Isle of Wight; February 24, 7 p.m.

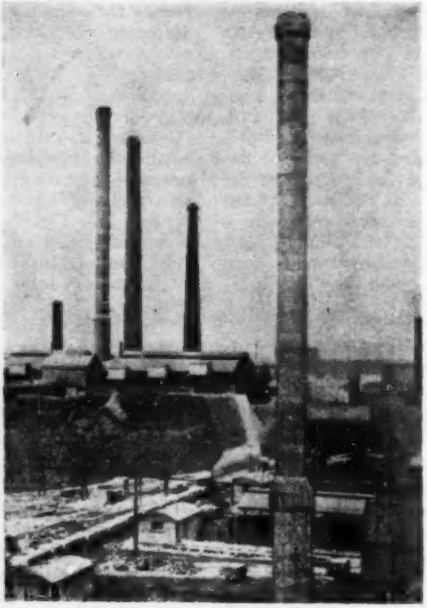
Clerical Methods in Builders' Offices, by K. C. Symons at the Technical College, Neath; February 25, 7 p.m.

Practical Formwork, Design, and Construction for Concrete, by J. G. Richardson at the Medway College of Technology, Chatham; February 26, 7.15 p.m.

FIFTY YEARS AGO.

From "Concrete and Constructional Engineering", February, 1910.

Reinforced Concrete Chimneys at Northfleet.



The illustration shows some chimneys at the cement works of the Associated Portland Cement Manufacturers, Ltd., at Northfleet, Kent. Two of the chimneys are of reinforced concrete and had been recently completed in 1910. "The taller chimney is 247 ft. in height above bottom of foundations; the thickness of the shell up to 62 ft. above the ground-level was as follows: outer shell, 12 in.; cavity, 4 in.; inner shell, 4 in. Above this the chimney consisted of a single shell 9 in. in thickness. The reinforcement in the shell consisted of rings of steel $\frac{3}{8}$ in. diameter, spaced 18 in. apart, and vertical bars formed of $1\frac{1}{4}$-in. × $1\frac{1}{4}$-in × $\frac{3}{16}$-in. T's." The smaller chimney is 130 ft. high, the shaft being reinforced similarly.

Tests of Water for Concrete.

Mr. K. H. Brittain writes as follows regarding the review of B.S. No. 3148 in our number for December, 1959.

"Many engineers will prefer the method, which their grandfathers established, of testing the suitability of water in a way which they themselves understand with equipment available in concrete laboratories. The alternative of specifying the water on the lines of the French and U.S.A. recommendations (which were duly considered by the Committee) involves the use of a chemical analytical laboratory to produce figures which have no obvious meaning for most engineers. The language in the British Standard is simple and sensible; the cost is high, but surely this is inevitable if a complete Government subsidy is to be avoided. I hope your paragraph on this Standard will not stop engineers reading it and using it."

MISCELLANEOUS ADVERTISEMENTS.

Situations Wanted, 5d. a word : minimum, 12s. Situations Vacant, 6d. a word : minimum, 15s. Other miscellaneous advertisements, 6d. a word : minimum, 15s. Displayed advertisements, 40s. per column inch. Box number 1s. extra.

Advertisements must reach this office, 14 Dartmouth Street, London, S.W.1, by the 23rd of the month preceding publication.

SITUATIONS VACANT.

SITUATIONS VACANT. Consulting engineers have vacancies for reinforced concrete detailers, and designer-detailers. Salaries in accordance with experience. Luncheon vouchers. Apply in writing to BYLANDER, WADDELL & PARTNERS, 169 Wembley Park Drive, Wembley, Middlesex.

SITUATIONS VACANT. E. J. COOK & CO. (ENGINEERS) LTD. require five reinforced concrete designer-detailers for expanding design office.! Not less than ten years' experience, H.N.C. or similar level. Salaries £800-£1200 per annum according to experience and ability. Five-days' week. Luncheon vouchers. Superannuation scheme after twelve months' service. Application forms from 54 South Side, Clapham Common, London, S.W.4 (Macaulay 5522).

SITUATIONS VACANT. Small structural engineering office, London, W.C.1 area, with extensive practice, requires additional assistants. Capable men from graduateship upwards required for high-class miscellaneous work generally, foundations, dangerous structures, steel, concrete and timber, and able to work with minimum supervision. Reply in confidence, with full particulars, and salary required, to BOX 4634, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATIONS VACANT. Detailer and designer-draughtsmen required for rapidly expanding reinforced concrete design office. Permanent superannuated positions. Five-days' week. Excellent working conditions in modern offices with canteen. Write, stating experience, age, and salary required, to THE SECRETARY, THE ROM RIVER CO. LTD., 100 Stewarts Road, Battersea, London, S.W.8.

SITUATIONS VACANT. Assistant engineers, steelwork designer-draughtsmen, reinforced concrete designer-detailers, and detailer-draughtsmen required for varied and interesting work on structures for industrial, commercial, medical, and residential buildings. Five-days' week. Luncheon vouchers. Apply, with details of experience, and salary required, to JOHN F. FARQUHARSON & PARTNERS, Chartered Structural Engineers, 34 Queen Anne Street, London, W.1. Telephone Langham 6081.

SITUATIONS VACANT. Reinforced concrete designers and detailers required. Minimum three years' practical experience on structural work. Good salary and prospects for right men. Written applications to JOHN LIVERSEDGE & ASSOCIATES, 42 Portland Place, London, W.1.

STRUCTURAL ENGINEERS

ENGINEERS required in Architect's Department, London County Council. Up to £1,135 (under review) and with good prospects.

(*A*) *Structural Engineering Division.*—Extensive programme includes multi-storey flats, schools, offices, warehouses and other buildings.

(*B*) *Structural Engineering Division.*—To deal with applications in respect of special structures under Part IV of London Building Act (A), 1939, and the constructional by-laws. Interesting work involving consideration of unconventional forms of construction.

(*C*) *District Surveyors' Service.*—Work mainly outside involving negotiations with architects, engineers and surveyors and supervision of works in progress.

Application form and particulars from HUBERT BENNETT, F.R.I.B.A., Architect of the Council, EK/112/59, County Hall, London, S.E.1. (2629.)

Truscon

in 1960

Truscon drawing offices are now busier than ever, and interesting, challenging schemes of great variety are arriving at our office every day. This means that our reinforced concrete design staff, which over the years has been steadily growing, now needs the support of extra men, and, essentially, men of the right character and quality.

We hope that these men will help to maintain Truscon's own tradition of quality—and this applies *both* to construction *and* design. Indeed it may be that the early collaboration between our design and construction staff, together with the constant interchange of information between office and site which an organisation such as Truscon permits, will of itself prove an attraction to the ambitious and imaginative, yet experienced, men we are seeking for our design offices.

The following positions are vacant:

London

Two reinforced concrete design engineers, with first-class experience of both project schemes and working drawings. Two reinforced concrete detailers, again with first-class experience.

Harlow, Birmingham and Manchester

In each office: one designer and one detailer with similar qualifications to the above.

Please write initially to our Director—Engineering at Truscon House, Lower Marsh, London, S.E.1, giving brief details of your qualifications, positions held, experience gained and salaries earned. We are anxious to give applicants every opportunity to justify themselves at an interview, which will be in confidence and can, if necessary, be arranged outside business hours.

Jobs with Truscon are, subject to usual conditions of employment, permanent and secure yet progressive. Salaries are good, as are holidays and sick pay entitlement. We have a good pension scheme, with dependents' benefits, and a profit-sharing scheme for staff. Promotion is by merit alone, and although we already have a number of mature young men holding down responsible posts, there's always room for more. **We shall be pleased to hear from anyone who would like to discuss the possibilities of joining Truscon in 1960.**

SITUATIONS VACANT. South London consulting engineers require experienced reinforced concrete engineers, designer-draughtsmen, and detailers. Applicants should have a minimum experience of three years in position applied for. Salary commensurate with experience and ability. Luncheon vouchers, and five-days' week. Please write, giving details of age, qualifications, and experience, to LEONARD & GRANT, 344 South Lambeth Road, London, S.W.8.

SITUATION VACANT. Manager required for rapidly-expanding sectional concrete building works. Must have good organising ability and be strong disciplinarian. Duties are to supervise and control all departments of this company, which include mould, carpentry, steel fabrication, despatch, and erection departments. This is a permanent position, and offers good prospects to suitable applicant. Please write in complete confidence, giving details of experience, and present salary, to MANAGING DIRECTOR, W. TIBBETS & SONS LTD., Barford Road, Bloxham, Oxon.

SITUATIONS VACANT. Structural and civil engineers require senior and intermediate designer-detailers experienced in either (1) reinforced concrete, or (2) structural steelwork. Excellent opportunities in an expanding organisation for the right men. Positions are pensionable, and offer first-class experience. Box 4639, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Keen, conscientious young production engineer experienced in concrete techniques, required for position in expanding precast, cast stone and reinforced concrete industry in Southern county. Ability to organise and assist in supervision of work in maintaining high standard of products. Excellent prospects. Write, stating age, experience, present situation, any qualifications, and salary required. Replies, treated in strict confidence, to Box 4641, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATIONS VACANT. Reinforced concrete specialist firm requires designer-detailers. Interesting and varied work. Some previous experience. Write CHIEF ENGINEER, CAXTON REINFORCED CONCRETE LTD., 45 Bedford Road, London, W.C.1.

SITUATIONS VACANT. Civil Engineering Assistants required for site work on contracts. The work is varied and interesting with opportunities for promotion and study of new methods. Applicants should be between the ages of 26 and 32, and hold a degree in civil engineering or equivalent. They should have had a minimum of 3 years with a contractor on site work, which must have included setting-out and progress measurement. Experience in design of formwork and other temporary works, control of concrete quality would be an advantage. Apply in writing, giving brief details of qualifications and experience, also stating age, and salary required, to The CHIEF ENGINEER, THE DEMOLITION & CONSTRUCTION CO. LTD., 3 St. James's Square, London, S.W.1.

SITUATIONS VACANT. Junior Civil Engineers required to work on sites with excellent opportunities for training. Applicants should be graduates or equivalent and should be between the ages of 20 and 26. Apply in writing, giving brief details of qualifications and experience (including vacation course work), also stating age, to The CHIEF ENGINEER, THE DEMOLITION & CONSTRUCTION CO. LTD., 3 St. James's Square, London, S.W.1.

SITUATION VACANT. W. & C. FRENCH LTD. urgently require designer/detailer mainly for reinforced concrete design and detailing. Applicants must be keen to learn about new methods and types of construction. Apply in writing, stating age, salary required and full details of experience, to PERSONNEL MANAGER, 50 Epping New Road, Buckhurst Hill, Essex.

SITUATION VACANT. Experimental or assistant experimental officer required for building materials research laboratory. Applicants should have a degree in physics, engineering, or building technology, or Higher National Certificate or equivalent, and preferably some experience of mechanical testing work. The appointment will be made at an initial salary appropriate to qualification. Apply, DIRECTOR OF RESEARCH, THE CHALK LIME AND ALLIED INDUSTRIES RESEARCH ASSOCIATION, Church Street, Welwyn, Herts.

SITUATIONS VACANT. Reinforced concrete detailers and designers required in North West London. Three-weeks' paid holiday, and excellent prospects in small expanding firm. Telephone Maida Vale 7890.

SITUATIONS VACANT. Air Ministry Works Designs Branch requires in London structural engineering designer draughtsmen for reinforced concrete or structural steelwork of all types. Applicants must have adequate training and several years' experience. Some site experience and possession of recognised technical qualification an advantage. Financial assistance and time off may be allowed for recognised courses of study. Promotion and pension prospects. Five-days' week with 18 working days leave per year initially. Salary for Grade III ranges from £680 (at age 25) to £900 per annum. Commencing salary dependent on age, qualifications and experience. Also vacancies in higher grade for suitably qualified candidates on range from £895 to £1,055 per annum. Applicants, who must be natural born British subjects, should write to Air Ministry, W.G.c, Lacon House, Theobalds Road, London, W.C.1, or to any Employment Exchange (quoting Order No. Kings Cross 3745) giving age, details of training, qualifications, full particulars of former posts held and copies of any testimonials. Candidates selected will normally be interviewed in London and certain expenses reimbursed.

THREE REPRESENTATIVES REQUIRED

Opportunities for three enthusiastic young men to obtain positions on Sales Technical Staff of Company with renowned products indispensable to reinforced concrete construction. Initially mobile over 50-mile radius of following approximate locations:

1. South Coast–London.
2. Tipton–Wolverhampton.
3. Leeds.

Knowledge of reinforced concrete, and driving licence advantageous.

Applicants must be of pleasant personality, keen, energetic, conscientious, adaptable, and should have been educated to the standard of G.C.E.

Written applications, treated in strict confidence, with full particulars, details of qualifications, etc., to Box 4640, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

GENERAL MANAGER

Thoroughly experienced and capable general manager required to take complete charge of wire straightening, cutting and bending works. Duties will include sales and purchase of raw material. Lucrative position and bonus scheme, with excellent possibilities of advancement. Apply in strictest confidence, detailing experience, to Box 4642, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

BRITISH RAILWAYS WESTERN REGION

Applications are invited for Structural Draughtsman experienced in preparing estimates and contracts for the supply and erection of steel and concrete bridges, etc. Drawing office and costing experience essential. Salary range £833/903.

Travel concessions, holidays with pay, with prospects of promotion and permanency, and membership of Superannuation Fund.

Applications stating age, previous experience, etc., to Chief Civil Engineer, B.R. Western Region, Paddington Station, London, W.2.

SITUATION VACANT. W. & C. French Ltd. urgently require architectural draughtsman and practical building detailer for interesting work of considerable variety. Apply in writing, stating age, salary required and full details of experience, to Personnel Manager, 50 Epping New Road, Buckhurst Hill, Essex.

SITUATIONS VACANT. Consulting engineers urgently require additional staff in London and Darlington. Engineers and draughtsmen for both reinforced concrete and steelwork. Full particulars to F. R. Bullen & Partners, Dacre House, Dean Farrar Street, London, S.W.1.

SITUATIONS VACANT. Civil and structural. Graduate engineers and designer-draughtsmen required for all types of design works on large civil and structural engineering projects in the U.K. and oversea. Resident engineer positions also available. A high rate of earnings is paid in this firm to those with initiative and ability. London Office of R. T. James & Partners, Consulting Civil Engineers, 6 Lower Grosvenor Place, London, S.W.1.

SITUATION VACANT. Experienced structural draughtsman required. Generous salary offered for first-class man capable of fast, accurate detailing and with the ability to work without close supervision. Please apply to R. L. Bourgui & Partners, Thermix House, Kingston-upon-Thames, for an appointment. (Elmbridge 0439 or 0888).

SITUATION VACANT. Reinforced concrete specialist firm requires designer/detailer. Interesting and varied work. Luncheon vouchers, pension scheme, etc. Only experienced men need apply. Write the Reinforced Concrete Steel Co. Ltd., 54 Victoria Street, Westminster, S.W.1.

SITUATION VACANT. Civil engineering assistant required for design and drawing of reinforced concrete industrial structures and foundations. Apply to the Chief Engineer, The A.P.C.M. Ltd., Portland House, Tothill Street, London, S.W.1.

SITUATION VACANT. Draughtsman-estimator for interesting work in connection with roof and floor beams. Opportunity to progress with a rapidly-expanding company. Pension scheme, and canteen facilities. Apply, giving full details of age, experience, and present position, to the Office Manager, Marley Concrete Ltd., Peasmarsh, near Guildford, Surrey.

SITUATION VACANT. Senior engineer required for London professional office. Must have professional qualifications, preferably degree, and at least five years' design experience in structural reinforced concrete. Knowledge of steelwork an advantage. Age limit 30–40. Candidates should have site experience, and be capable of handling contracts from start to finish. The work is varied and offers scope for initiative. A good salary will be offered. Apply, stating experience, and salary required, to Farmer & Dark, Romney House, Tufton Street, Westminster, S.W.1.

SITUATIONS VACANT. Reinforced concrete detailers for London professional office. Experience of steelwork an advantage but not essential. The work is varied and offers scope for initiative. Five-days' week. Please apply, giving full details, and salary required, to Farmer & Dark, Romney House, Tufton Street, Westminster, S.W.1.

SITUATIONS VACANT. Consulting engineers in Westminster require capable assistants for varied structural and civil engineering work. Five-days' week. Luncheon vouchers. Write or telephone: Maurice Nachshen & Partners, 58 Victoria Street, S.W.1., VIC. 0285.

GENERAL MANAGER

PRECAST CONCRETE PRODUCTS

Firm of precast concrete manufacturers, operating in central Scotland, having a progressive programme in hand, require a general manager, fully experienced in all types of precast concrete products. The appointment will relate particularly to the production side, but experience in all other branches will be necessary. An attractive salary and conditions, including superannuation scheme, will be offered to suitable applicant who should be in the 35–45 age group. Replies should give fullest particulars of experience and will be treated in strict confidence. Box 4643, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

PARTNER.

Structural Consultant, N.W. London, in practice six years, is thinking in terms of rapid expansion and is interested in hearing from competent designer-draughtsman to take full charge of drawing office. Applicant should be prepared to enter partnership agreement and eventually to take over the growing practice. Write fully, in confidence, to Box 4638, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

SIMON-CARVES LTD.

have a vacancy in their Building & Civil Engineering Dept. for a

FORMWORK DESIGNER/DETAILER

Applicants must have H.N.C. (Struct. or Mech.) or an equivalent standard of knowledge and wide experience of design and application of formwork structures for industrial and general civil engineering work. The post is permanent and pensionable and offers good prospects in an expanding department.

Starting salary up to £1,000, depending on experience and qualifications. Send brief relevant details to Staff and Training Division, **SIMON-CARVES LTD.**, Cheadle Heath, Stockport, Cheshire, quoting Ref. ZR. 45.

GEORGE WIMPEY & CO., LIMITED

invite applications from

STEELWORK DESIGNER/DETAILERS
STEELWORK DETAILERS
REINFORCED CONCRETE DESIGNER/DETAILERS
REINFORCED CONCRETE DETAILERS

Rapid expansion of our Head Office organisation offers first-class opportunities for keen and experienced men in the field of Chemical and Refinery structures.

These appointments carry attractive salaries; personnel benefits include opportunity to join pension scheme, and full restaurant facilities.

Apply, giving full details of experience, to:

R. E. J. Worth, M.I.C.E.,
Planning Department,
27 Hammersmith Grove, London, W.6.

SITUATIONS VACANT. Experienced designers and draughtsmen in reinforced concrete required by consulting engineers in Golders Green. Progressive positions. Five-days' week, pension scheme. Box 4648, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

DESIGN ENGINEERS AND DESIGNER-DETAILERS

Applications are invited for the following progressive and permanent appointments to our staff for a large and varied programme of reinforced and prestressed concrete work:

Design Engineers.—Chartered structural or civil engineers with several years' experience in design, and a good knowledge of structural theory. Quick, accurate and original designers, capable of working without supervision, preparing outline scheme drawings and estimating quantities for insitu and precast concrete structures.

Designer-detailers.—Capable of quick, accurate design and detailing from outline schemes.

Excellent working conditions in new offices near Manchester. Good salaries plus annual bonus, superannuation, three weeks' holiday. Written applications to:

Matthews & Mumby Limited,
Oldham Street,
Denton, Manchester.

CIVIL ENGINEERING STAFF

SITE STAFF

The following are required for a variety of civil engineering contracts.

Senior Agents (Reference PE.8), having a minimum of ten years' experience with major contractors. Essential that applicants have had control of large competitive projects involving piling, excavation, and mass and reinforced concrete.

Agents (Reference PE.9) must have had up to five years' experience similar to the above on contracts of approximately £250,000 in value.

Engineers (Reference PE.10) must have had a minimum of two years' site experience on heavy civil engineering contracts and must have passed Parts A and B of Institution of Civil Engineers or have equivalent qualifications.

HEAD OFFICE STAFF

Civil Engineer (Reference PE.11) required to control staff who are engaged on construction-methods planning at the tender stage of contracts. Must have had considerable experience of site work plant and labour utilisation and outputs, in the widest field of civil engineering. This is a new senior Head Office appointment, created by expansion, involving brief visits to sites.

All these posts are permanent and pensionable. Applicants should give full details of their age, experience, qualifications, present position and salary, and quote the reference number of the particular vacancy in which they are interested. Apply to Simon-Carves Limited, Contract Labour Department, Cheadle Heath, Stockport, Cheshire.

SITUATION VACANT. A well-known company of reinforced concrete engineers and contractors requires for an interesting vacancy in their London design office a well-qualified design engineer, with good experience both in the preparation of project schemes and working drawings. Salary up to £1600 per annum, with contributory pension scheme, etc. Box 4647, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

ROBERT M. DOUGLAS (Contractors) LTD.

require

Designer-detailers immediately for work on multi-storey concrete structures. Apply, giving age, full details of experience, and salary required, to 395 George Road, Birmingham, 23.

SITUATION WANTED.

SITUATION WANTED. Structural engineer, B.Sc., 30, with eight years' drawing office and site experience of in-situ and precast reinforced concrete, used to acting on own initiative and to carrying considerable responsibility, seeks senior position in London area where technical qualifications and experience can both be used to advantage. Good knowledge of languages. Box 4645, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

PROFESSIONAL SERVICES.

PROFESSIONAL SERVICES. Structural engineer, experienced in the design and detailing of reinforced concrete and steel structures, will accept commissions from consulting engineers on a part-time basis. Box 4644, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

PROFESSIONAL SERVICES. Reinforced concrete engineer, with long experience, offers spare-time assistance to the profession. Designing and detailing. Box 4646, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

FOR SALE, WANTED OR HIRE.

FOR SALE. Steel tubes and fittings, sections, strips, blanks, etc. List on request. E. Stephens & Son Ltd., Bath Street, London, E.C.1. Telephone Clerkenwell 1731.

FOR SALE. Unused 500 tons three-mould concrete slab press, rotating table, self-contained oil hydraulic pumping unit. 400 tons two-station concrete slab press, by Fielding & Platt, with pumping unit. Reed Brothers (Engineering) Ltd., Replant Works, Woolwich Industrial Estate, London, S.E.18. Tel. Woolwich 7611/6.

WANTED.

COMPRESSION AND TRANSVERSE CONCRETE TESTING MACHINE REQUIRED. CAPACITY OF AT LEAST 150 TONS. PLEASE COMMUNICATE FULL DETAILS TO GEORGE W. BRUCE LIMITED, 106 CROWN STREET, ABERDEEN

FOR HIRE. Lattice steel erection masts (light and heavy), 30 ft. to 150 ft. high, for immediate hire. Bellman, 21 Hobart House, Grosvenor Place, London, S.W.1.

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